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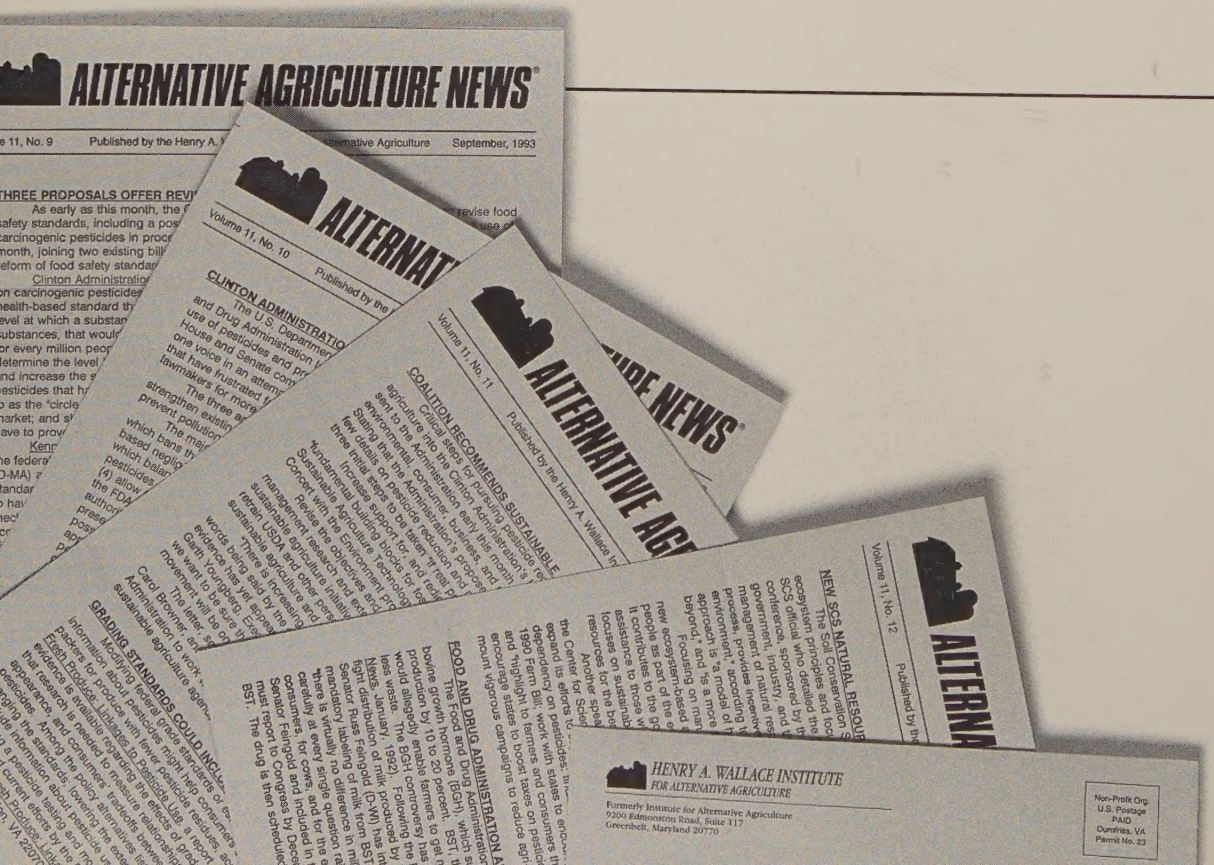

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Wallace Institute Information

The Henry A. Wallace Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of cost-effective, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover photo shows a typical scene of cabbage production in Malaysia's Cameron Highland—the subject of the case study reported on pp. 175-184. Cabbage beds are commonly terraced, often on more steeply sloping hillsides than in this photo. Much of Malaysia's cabbage is grown with sprinkler irrigation under low pressure. Toward the left rear of the photo are sheds used for storing fertilizers, agricultural chemicals, and other cultivation supplies. Photo provided by the Malaysian Agricultural University research team.

Alternative Agriculture Policy: A New Time To Choose

What federal policies and programs are now needed to foster a sustainable agriculture in the U.S.? How can current policies be modified or redirected to serve that purpose? These are questions receiving more and more attention by proponents of alternative and sustainable agriculture. Driving this interest is the realization that food and agricultural policies have not effectively encouraged sustainability. While ensuring adequate production, past and current policies have failed to give equal consideration to other requirements of a sustainable agriculture, such as natural resource conservation, environmental protection, food safety, and social acceptability.

The 1990 Farm Bill began to recognize and correct these policy shortcomings by modifying commodity price and income programs, increasing support for conservation, and expanding sustainable agriculture research and education. But spotty implementation of the legislation, continuing differences in views about the meaning of sustainability and the best way to achieve it, and the enormity of the federal budget deficit could now conspire to keep sustainable agriculture from occupying an undisputed place on the federal policy agenda.

Therefore, proponents of sustainable agriculture see the urgent need to identify and create imaginative policy measures to support sustainability. They sense the importance of developing sound information about the likely effectiveness and impacts of alternative policies, that is, to inform the policy process with facts as well as opinions and guesses.

To help carry out those steps, a National Sustainable Agriculture Dialogue has been established, with the participation and support of the Wallace Institute and many other like-minded organizations. The Dialogue was convened in Washington, D. C., in late February 1993 to begin to identify policy options for consideration in the 1995 Farm Bill. A second national conference, convened to explore and refine these and other policy options arising out of the Dialogue process, will be held in late February, 1994.

Alternative agriculture policy was also the subject of the Wallace Institute's 10th annual symposium, held on March 1, 1993. Titled "Alternative Agriculture Policy: A New Time to Choose", the symposium began by revisiting two landmark reports issued by the U.S. Department of Agriculture in 1980-1981. One was titled **Report and Recommendations on Organic Farming** (1980). The other was **A Time to Choose** (1981), known popularly as the USDA "structure of agriculture" report.

As the decade of the 1980's began and a new political party took office, both of these reports were spurned or moved aside. They deserved a better fate. Both had much to say about the problems of American agriculture and those policy changes needed to foster a more sustainable agriculture.

The morning session of the symposium looked back to the setting and substance of these reports. The afternoon session looked ahead.

We have chosen this issue of the Journal to share with our readers summaries of the following presentations and discussions at the symposium:

Looking Back...

- Lynn Daft, vice president of the consulting firm, Abel, Daft and Earley, began by tracing the circumstances and issues that led to USDA's assessment of the changing structure of agriculture, what the study found out, and how the results might relate to the current pursuit of a sustainable agriculture.
- Richard Harwood of Michigan State University, in a similar fashion, traced the background, findings, and implications of the USDA organic farming report.
- A panel responded to the presentations by Daft and Harwood. The panelists were Bob Papendick, USDA Agricultural Research Service in Pullman, Washington, and a member of the organic farming study team, Cornelia Flora, sociologist at Virginia Polytechnic Institute and State University, and Paul Johnson, Iowa farmer and member of the Board of Directors of the Wallace Institute.

Looking Ahead...

- Kathleen Merrigan, former member of the Senate Agriculture Committee staff, drew on her experience in the 1990 farm bill process to outline future policy options and strategies.
- Bob Bergland, National Rural Electric Cooperative Association and former Secretary of Agriculture, shared his recollections as well as his views of the future.
- In addition to the foregoing talks, the symposium featured a roundtable panel discussion on a broad range of policy issues and options. The panelists were: Roger Blobaum, Blobaum & Associates; Chuck Hassebrook, Center for Rural Affairs; Maureen Hinkle, National Audubon Society; Jim Jontz, former Indiana Congressman; Fred Kirschenmann, North Dakota farmer; and William Lacy, Pennsylvania State University. The roundtable moderator was Katherine Clancy, Syracuse University and Institute Board member.

A major topic of discussion was the relationship between agricultural structure and sustainability. Several panelists commented that, compared to conventional farming systems, sustainable systems require a higher level of skills and on-site management.

Therefore, family farms are more conducive to a sustainable agriculture because the farmer can give more attention to each acre and each animal.

The panel also was concerned about how biotechnology would affect structure and sustainability. In principle, biotechnology is a tool that can have either positive or negative effects on both the environment and on farms of various sizes. What actually will happen depends on how closely this technology is regulated and how involved farmers and the public are in deciding research priorities and regulatory policies.

Budget pressures on the commodity programs came in for considerable discussion. Public support for traditional programs is dwindling. The panelists emphasized that if the programs are to continue, they will have to have broader appeal, especially by providing incentives for good stewardship and environmental protection.

Other themes in the discussion included: the need for stronger ties between farmers who use reduced-chemical methods and consumers interested in pesticide-free foods; the importance of greater cooperation between family farm advocates and environmentalists; the need for innovative extension educational approaches in sustainable agriculture; the shortage of new farmers and the need to open more opportunities for those who wish to enter farming; and the serious social and economic problems of much of rural America.

The splendid cooperation of the authors, panelists, and moderators, whose collective efforts made this special policy symposium a success, is gratefully acknowledged. May the ideas and perspectives represented here help to guide and inspire those who seek to develop and implement new policy changes supportive of agricultural sustainability. As the symposium title indicates, now really is the time to choose.

Garth Youngberg and Neill Schaller
Symposium Co-Chairs

A look back at the USDA Report on the Structure of Agriculture: A Time to Choose

Lynn Daft

Origin of the Report

A Time to Choose came about in a setting of substantial turmoil. In the late 1970s, agriculture felt that it was on a roller coaster. Earlier in the decade, it had experienced the huge sales to the Soviet Union, short crops around the world, very high prices, and very high incomes. Then it came down the hill into a very unstable period that was substantially different from the relative stability of the 1950s and 1960s. Energy problems, which had begun early in the 1970s, had not had much of an effect while prices and incomes were high, but when the boom ended, the high cost of energy hurt farmers badly. The general economy was seriously overheated, and inflation was very high. The budget situation, which in retrospect seems tame compared with today's, looked very threatening at the time. In fact, from 1979 to 1980 the deficit increased 80%, something that was very much on people's minds as they were judging policy options. Finally, unusually rapid structural changes were taking place, with farms becoming larger but fewer.

These changes raised a basic question about the intent of farm policy. This policy, dating back to the 1930s, had been sold to the public on the premise that it preserved an agricultural structure based on the family farm, but it didn't seem to be having that effect. Program costs were rising and there was agitation for increasing support levels, but the structural aspect just seemed to deteriorate.

A Time to Choose was not the first federal study to deal with the structure question. Both the General Accounting Office and the Congressional Budget Office had issued reports on this topic in 1978. Then came the tractorcades of 1979, which forced the Secretary of Agriculture to move into another office for a while and gave him an unusual opportunity to think and reflect.

The result was a decision by the Secretary to take a serious, intensive look at what was happening to the structure of agriculture. The effort was launched in Spring 1979, and late in the year ten regional hearings were held around the country. The final report, issued in January 1981, was the most comprehensive look ever taken at the

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performance of farm policy, particularly with regard to structural objectives.

It is important to know the setting in which this study was undertaken to know what the authors were thinking. First, there was a widespread belief that we were out of the era of surpluses and that shortages were going to rule the day. There also was a belief, for which there was a fair amount of evidence, that increases in productivity and yields were slowing, which would tighten the market. Rates of return in agriculture generally were seen as favorable. The problem there was that much of that return was in capital gains and therefore wasn't being realized as income; these gains could only be captured by selling the farm. Also, capital gains were attracting non-farm investors into agriculture. Finally, people believed that most of the economies of large-scale farming operations had been realized. Initially we had expanded our land base and later we adopted mechanical and then chemical technologies. Now, however, it seemed we were hitting against a ceiling, with no great new technologies on the horizon. The effect of all these conditions was increased concentration, not just among producers but also among processors, first the handlers, and then through the system.

Whatever measure of the agricultural situation one picks, it is easy to understand why people thought we were in an era of exceptional change. For example, agricultural exports were increasing rapidly; if you extrapolate the 1970-1979 trend line, you would see why exports were expected to soar. The same was true for farm assets (mainly land values). Even when adjusted for inflation, farm assets were rising very rapidly, as was farm debt.

In summary, it seemed we were on a collision course: markets were getting tighter, but farmers were not so well off. Moreover, the farm community was in tremendous political upheaval. The 1977 farm bill was passed only after much back-and-forth between the Administration and Congress, with Congress pressing for higher price supports. After it was passed, most of its major commodity provisions were modified every year for the next three years to try to keep up with inflationary effects. However, the farm bill still did not have the structural effects that everyone assumed was characteristic of farm bills.

The report began by reviewing this setting and identifying the issues that were giving us trouble, the issues that we needed to reexamine to see whether we were on the right track. To understand how the study team dealt with these issues, it is important to understand the assumptions they were working under: that land prices would continue to inflate rapidly; that it would be easy for farmers to get the credit they needed to expand; that both farm debt and asset values would continue the trend of the 1970s; that exports and world demand would continue to rise; and that most of the economies of scale for farms with annual sales in the $40,000 to $200,000 range had already been realized.

Issues Covered in the Report

The first issue the study team examined was land ownership, where not surprisingly they found increasing concentration. With outside investors coming in, ownership was increasingly separated from farm operation. High land prices made it difficult to enter farming and to transfer land to the next generation. There were several causes for this problem, including tax policy (as discussed later) and easy credit that allowed more expansion and concentration than was wise. The team recommended that farm program benefits be targeted to operators so as not to reward non-operator investors. They also recommended making intergenerational transfer easier, for example, by having the Farmers' Home Administration focus on that goal rather than on financing relatively large operations.

Another issue was soil and water conservation. The pressure for increased production to meet higher demand was putting more strain on natural resources. The team found that USDA's production-related activities were not coordinated with its conservation activities, and that there were problems with both groundwater and erodible lands. They recommended shifting some erodible land out of production, perhaps in connection with the farm programs, perhaps through long-term contracts. Other recommendations included: encouraging states to become more involved in conservation; setting the price of water more appropriately; and building an improved information system that could be used in charting conservation policy.

Tax policy also was important. Major problems included estate tax laws, cash accounting provisions, and treatment of capital gains. These all caused higher land prices, more concentration and expansion, and substitution of capital for labor. The team made two major recommendations: a thorough review of tax policies, paying particular attention to farm structure; and greater USDA involvement in formulating tax policies, so that farmers' interests would be represented. (In several places the report recommended that USDA become involved in the many important policy actions taking place in other agencies such as the Treasury or the Department of Labor.)

Commodity policy also received much attention. Not surprisingly, the study team found that the programs favored larger operations and that benefits were being capitalized in land values. The key problem for commodity policy no longer was that income was low, but that our intensive involvement in international markets had created great instability. Farm policy was being driven by short-term crises rather than long-term objectives, but attempts to reform the situation had been strongly resisted. To deal with instability, the study strongly recommended expanding the grain reserve. It suggested tying deficiency payments (the principal form of commodity program benefits) more directly to small and medium size operations, linking land diversion to conservation, perhaps using bids, and getting out of the costly business of emergency credit and disaster payments as much as possible.

The study team found that agriculture generally had good access to credit. However, easy credit was a major cause of expansion, inflated land values, and increasing concentration, which in turn led to a cost-price squeeze for many farmers. The team believed that the Farmers' Home Administration had expanded too rapidly and had been too much a part of the easy credit. They recommended that agriculture continue to have good access to credit, but primarily through the private market. Public credit, in contrast, should be focused on young, beginning, and limited-resource farmers, with less emphasis on emergency credit.

Regarding public research and extension policy, the authors believed strongly that research should not be stopped, and that one cannot turn the clock back on technology. Rather, technology had to be made to serve our national objectives. This involves two key elements: research priorities, and the institutions that will do the research. The choice of research priorities strongly affects the technology that results and the uses it serves. The team recommended that research focus more on land- and labor-intensive technologies and less on those that are energy- and capital-intensive. Since USDA research funds largely end up in the states, it was thought that researchers were paying more attention to local needs grounded in the status quo than to innovative anticipation of technologies that might be developed to achieve other objectives. The team recommended giving priority to research on the needs of small and medium-size farms, thinking seriously at an early stage about who would benefit from the research, and giving much more attention to environmental, health, and nutritional issues.

Regarding agricultural labor, it was hard to find anything good to say; both the employees' and the employers' sides had problems. The recommendations were for USDA to work with the Department of Labor to fashion careers that would lead somewhere; to work with employers on employee management; and to do research that would make employment more stable, make the jobs meaningful, and improve working conditions.

Finally, in trade policy, the study team was very concerned about the tightening of world markets and our major international involvement. They recommended integrating trade policy with domestic farm policy and encouraging the establishment of food reserves by other countries, with costs to be shared. They also called for more international development assistance and more efforts on value-added exports and exports that used less natural resources.

The overall conclusion was that most policies involving taxes, commodity prices and credit favored larger operations. However, the principal gains to society from moving toward larger farms had largely been realized, so that there no longer was much justification to move further in that direction. Therefore, policies should be modified to support small and medium size operations instead of promoting increased concentration and expansion.

The Report and its Time

A Time to Choose was very much a product of its time, and it was influenced heavily by the trends I described earlier. The study took place in a particular setting under a particular set of expectations.

Looking back, we now can see that 1979-80 was a turning point and that one could have hardly picked a worse time from which to extrapolate past trends. No matter what trend is plotted, there is a sharp break between the 1970s and the 1980s. Commodity Credit Corporation inventories and outstanding loans on corn, dairy products, and other commodities offer a good example. In the late 1970s, inventories were low and relatively stable, but they shot up in the 1980s. Rates of return to equity, both from current income and capital gains, also changed sharply. In the 1970s, current income was declining because of the intense cost-price squeeze, and returns consisted mainly of unrealized capital gains. Around 1980, however, the situation reversed: land values crashed, and eventually cash income increased. The pattern of sudden change around 1980 was the same for exports, farm debt, and farm assets.

These changes arose partly from the new Administration's different philosophy and some early mistakes it made in administering these programs. Nevertheless, any administration facing the problems of the 1980s would have had a different outlook from what prevailed in the 1970s; it was not purely the result of a change in political party.

An interesting indication of how these developments affected structure is provided by the dramatic changes in the distribution of farm size. From 1970 to 1980, the proportion of farms selling less than $20,000 per year dropped by 20%, while the largest category went from 0.6% to 4.3%. From 1980 to 1991, however, the rate of change slowed significantly.

Although the report was a product of its time and although the times changed sharply in the 1980s, many of the its recommendations have been adopted, at least to some degree. Whether or not the report was responsible, its arguments helped to shape the debate that followed. It strongly advocated a long-term conservation reserve program and a reform of farm credit, both of which have since been adopted. It did not stress environmental, food safety and dietary issues as strongly as they probably would be today, but at least they were identified as important, especially the environment. The integration of trade and farm policy is much more important today than it was in 1979. Overall, therefore, although structural objectives might not have been responsible for the policies of the 1980s, the direction those policies took was highly compatible with structural concerns.

Perhaps the most significant outcome of that report was that it sowed seeds of doubt about the assumed relationship between commodity policy and agricultural structure. It questioned whether commodity programs achieved our objective of preserving small and medium size farms as the foundation of our agricultural system. The result was not so much that the programs were changed to make them achieve structural objectives. Rather, the report caused people to consider the programs as less justified, especially given the tightening budget situation.

The structure issue remains very much alive. It takes a different form compared to the past, but many of the same themes are still present. Today's structural arguments revolve less around the effects of farm policy. Instead, they are more concerned with private markets, especially with respect to where new technologies and consumer demand for more specialized, convenient products are taking us, and whether these developments might lead to more vertical integration and increased use of contracts, for example. In an industry as dynamic as American agriculture, structural change is likely to remain prominent, and with that change will come many more opportunities to make important policy choices.

A look back at USDA's Report and Recommendations on Organic Farming

Richard Harwood

The United States Department of Agriculture's *Report and Recommendations on Organic Farming* (1980) is destined to be a milestone in the evolution of agriculture's scientific paradigm. Such recognition, however, will come several years in the future and will require a key scientific breakthrough for full assessment of the "new world" its authors brought forward to the mainstream scientific community.

A careful rereading of the report touches almost as many raw nerves now, more than a decade later, as it did in 1980. Truly, its authors risked credibility and scientific careers to "tell it like it is," to quote Robert Papendick, who, along with James Parr, coordinated the study.

Without understanding how strongly the existing paradigm dominated agricultural science in the late 1970s and the extreme bias against organic agriculture that it generated among scientists, one cannot imagine the difficulty faced by an "official" team doing their utmost to study the issue objectively. Peer review of any such report would be daunting if not impossible. But I also find myself critical of the report, which undoubtedly will disappoint Drs. Parr, Papendick, Colacicco and Youngberg, study team members present at this conference. But my criticism stems as much from disappointment over science's failure to assess organic agriculture adequately, before 1980 and since then, as from shortcomings in the report. The courage and scientific objectivity of Secretary Bergland, and particularly of the study team, will one day be broadly recognized.

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Organic Farming as an Indigenous Knowledge System

The feature of *Report and Recommendations on Organic Farming* that most distinguishes it from other USDA reports of the time is that it dealt with an amorphous package of practices that constitute a truly indigenous knowledge system, as opposed to the commonly studied systems found in the scientific literature. As with any such indigenous system, practitioners assimilate knowledge from each other and from both historical and scientific sources. Organic practitioners tend to be well read. However, this knowledge is not conceptualized the way a scientific knowledge system is. Its underlying principles are not stated in scientific terms, and biological relationships commonly are described with phrases that suggest human characteristics, such as the need to focus on "soil health." Organic farming's focus on biological relationships made it seem irrelevant to most people in the 1960s and 1970s when agriculture was dominated by chemistry and engineering. The frequently heard charge that organic agriculture is based on "religion" rather than science therefore is not surprising. A perfect example is seen in a basic tenet of organic agriculture that one should "feed the soil, not the crop," a phrase that has been so maligned by scientists. It was against this background, and with these challenges, that the team started its work in the late 1970s. The team members were good scientists, well established in their fields, but they faced enormous difficulties.

Origin and Goals of the Study

A combination of factors brought the study about. The first was a realization that the agricultural development agenda had to be broadened. Second, a political constituency was demanding attention.

The original intent of the study was explained by Secretary Bergland this way:

> We in USDA are receiving increasing numbers of requests for information and advice on organic farming practices. Energy shortages, food safety, and environmental concerns have all contributed to the demand for more comprehensive information on organic farming technology. Many large-scale producers as well as small farmers and gardeners are showing interest in alternative farming systems. Some of these producers have developed unique systems for soil and crop management, organic recycling, energy conservation, and pest control. We need to gain a better understanding of these organic farming systems. . . . We must also identify the kinds of research and educational programs that relate to organic farming. (U.S. Dept. of Agriculture, 1980, p. iii)

The goal of the study, as stated by Anson Bertrand, USDA's Director of Science and Education, was "to learn more about the potential contribution of organic farming *as a system* for the production of food and fiber" (U.S. Dept. of Agriculture, 1980, p.v, emphasis added). The study team strongly believed in looking at organic farming as a system, and, therefore, did not

merely ask how bits or pieces of organic agriculture could contribute to a sustainable agriculture.

Although the study was undertaken to try to meet the needs of organic practitioners, it was very much concerned with environmental and social issues affecting mainstream agriculture. Whose problems did it address? Not those of organic practitioners, since practitioners would find little, if anything, to learn in it. However, for someone who knew nothing about organic agriculture, the report would be an up-to-date summary of the most important issues now on the sustainable agriculture agenda. It would go a long way toward dispelling many of the scientific community's myths and misperceptions about organic agriculture.

Sources of Information

The team began by going through the literature and by talking with key people in organic farming. They met with people in non-profit organizations and the farm community who were widely read and keenly aware of the important issues of the day. These people were at the forefront of change, although the issues that concerned them, such as farm size distribution, seem like old hat today.

Needing to look at a broad array of agricultural practices, the team made visits not only in the U.S., but also in Germany, Switzerland, England, and Japan. In Europe, organic agriculture had been practiced for decades. Its ideas already were well established there, and the team was exposed to a broad range of ideas and philosophies.

For the team to get a reading on the extent and makeup of the U.S. organic farming community, a survey was initiated of readers of *New Farm* magazine, published by Rodale Press. Scientists from the study team helped design the questionnaire, including information the team very much needed for their analysis. With follow-up letters by Bob Rodale, the team eventually got a response rate of 70%.

The team also did case studies of 69 farms. Secretary Bergland had charged the team with doing farm visits, starting with an organic farmer neighbor of the Bergland farm in Minnesota. The experience gained from those visits was a major influence on most of the team members, with many of the report's conclusions based on direct field observations. Not all team members made these visits, however, and specific pieces of the report done by those who didn't are evident. A few pages stick out as the views of someone on the outside who had not looked carefully at organic farming yet who presumed to know, from his own scientific background, why something would or would not work.

Definition of Organic Farming

The team considered all the key concepts of organic farming, the first question being how to define it. From the many definitions they found, the following was synthesized:

> Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. (p. xii)

This is typical of the definitions one normally hears. However, they then added the following:

> To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests. (p. xii)

This passage frames much of the agenda for the biological portion of sustainable agriculture that the LISA (now SARE) program focuses on. But the team added another important sentence:

> The concept of the soil as a living system which must be "fed" in a way that does not restrict the activities of beneficial organisms necessary for recycling nutrients and producing humus is central to this definition. (p. xii)

Here the team had clearly identified the central element, the thread that ties biological production systems together. This posed a real problem that even today we do not know how to handle. Identified by the team as a "problem of communication," at the end of the report it was described this way:

> The ambiguity of certain basic concepts of organic farming prevents their use as a firm basis for decisionmaking. For example, the concept of "feeding the soil" rather than the plant is unclear and is difficult to interpret in physically meaningful terms and difficult for scientists to relate to soil physical and chemical characteristics. (p. 83)

The team's conclusion was that "this barrier can be overcome by mutual education and understanding" (p. 83). (This seems to imply that if we could only "educate" organic practitioners we could get beyond philosophy to valid science, but they did say "mutual understanding.")

Findings

The team was especially concerned about how crop productivity on organic farms compared with conventional farms. They cited research data of the mid-1970s from the Midwest (Klepper et al., 1977; Lockeretz et al., 1978). Some 10 to 15% of organic farmers in the survey claimed their yields were higher, but most reported no difference, with a small portion reporting lower yields. The team had only scanty data to go on, but their conclusion has been supported by research during the past 13 years. When organic systems are well managed, as in the Rodale experiment and on many of the better farms, there is no difference in yield, except in dry years, when the organic yields may be higher.

The team pointed out the effects of organic methods on soil productivity and tilth, but the research on this topic still is not definitive. In the past two or three years there have been efforts to pull together the characteristics that go into soil health or soil quality. We are close to answering the basic questions: What are the relevant parameters, and how do we measure them? The American Society of Agronomy's North Central Committee on Soil Quality (NCR 59) has put out a list of procedures for assessing soil quality and

health, which seem to work, but the list needs much more follow-up.

Probably the weakest part of the study was its treatment of crop nutrient budgets. The team was very concerned that the organic farms were showing a yearly nutrient deficit of some 10 to 15 lb/A of P or K, which they considered a primary limiting factor that eventually would be a problem for all organic agriculture. This conclusion was based on the premise that nutrient input must at least equal the nutrient loss through removal of harvested product. This is generally true for systems in which large amounts of nutrients are removed, as in K removal in alfalfa hay. However, it seems not to hold for many production systems, except over very long periods.

The team did not know what to do about non-traditional soil additives, and scientists still do not. These are biological additives, such as enzymes, that are applied in very small quantities. There is a thriving industry dealing in such materials, but we do not have reliable data on them. Our understanding of biological processes in the soil still is not adequate to measure their effects, if any.

Animal production was covered only briefly, but farmers' testimony on lower veterinary costs and better animal health was reported. Here, too, recent research has borne out the conclusion. The lack of close confinement, more pasturing, and possibly the feeds that are used tend to promote better health. The data from the Thompson farm, for example (National Research Council, 1989, pp. 308-323), illustrate this.

Regarding economics, the team did a good job in summarizing the literature and reporting what farmers were telling them. They included a brief treatment of an economic model that compared crop rotations with monoculture corn or corn/soybeans. That analysis is typical of economic analyses of organic systems since then, which often repeat the mistake of not giving credit for the beneficial effects that one crop can have on another in the rotation. Rather, each crop is analyzed as though it were the only crop. No value is placed on the interactions between cropping systems and soil quality.

The report talked only briefly about the problems of conversion to organic methods, about which not much was known at the time. The team felt that the conversion process was primarily a matter of weed competition in the early years of nonchemical use. The lack of data about conversion, a lack that is almost as serious today, has caused many problems in research over the past decade. An assumption that is uniformly accepted by the organic community, whether in Europe, Japan, or the U.S., is that one must go through a conversion process of some three to five years, during which "something" happens in the soil. People who understand indigenous knowledge systems will put a lot of stock in an idea that is held in common by people with wide philosophical, geographic, and other differences, and even by groups of people who won't sit in the same room with each other. Researchers have been led astray by not understanding the need to go through a soil conditioning process in which biological populations in the soil presumably are shifted. Thus we have had many "organic"/conventional research comparisons where researchers applied appropriate organic inputs (they no longer just withhold chemicals and call it "organic"), but on a soil that had not been conditioned or converted. Granted, we do not yet completely understand the conversion process, but many scientists still have not grasped the idea that they need a "conditioned" soil if they want a truly organic treatment comparison. We still see "nontraditional" materials tested on a soil that has been farmed conventionally on an experiment station for several decades. This is not a scientifically valid test if a conversion process is necessary.

The team also dealt with the labor requirements of organic farming and its environmental effects, both of which have been studied a good deal in the past decade. The report contains considerable discussion of food safety, especially the effects of pesticides. Since then we have had the Delaney Report (National Research Council, 1987), among others. There has been a fair amount of work on the pesticide content of foods, which has included finding pesticides in organic foods in California. The effects of organic production on nutritional quality was brought up as an issue, but there has been little work on it. Rodale Press, USDA and others are beginning to take this issue up again, but it had been put aside for a long time.

Finally, the team talked about various obstacles to organic farming. These included the lack of information, lack of public support, lack of a marketing system, and problems of organic certification.

Reactions and Activities Following the Report

Organic practitioners generally regarded the report as reasonably good but brief. However, these were well-read people who could cite reference after reference on these issues. The report was not meant to educate them. Rather, it was intended to educate policymakers and the scientific community, and it had that effect.

An interested, curious minority of scientists have begun to see the potential of organic farming. Clusters of scientists in universities around the country and various policymakers began to follow up on the research ideas offered by the report. The majority, however, felt that the report was irrelevant because organic agriculture wasn't "practical." Its opponents seemed to think that it would just die a natural death. Its supporters had expected a storm of controversy, which did happen after the more recent publication of *Alternative Agriculture* (National Research Council, 1989). That report, coming from the National Academy of Sciences, seemed to pose more of a threat to the "conventional" paradigm. There was an organized rebuttal to it, but none for the organic farming report.

An important recommendation was for the USDA to appoint a permanent coordinator for organic affairs. Not only was this recommendation not followed, but the temporary appointment that had been made was later eliminated. However, that recommendation in essence has been implemented through the LISA (now SARE) program established under the 1990 farm bill. To some extent its coordinator is fulfilling the functions that had been envisioned in the organic farming report: coordination of information flow, coordination of funding, and a source of momentum for giving attention to sustainability within the federal government.

Today, farmer organizations are much stronger and more prevalent than they were in 1980, both for organic and for sustainable agriculture. In Michigan, for example, there are two organic organizations granting organic certification. There also is the Michigan Agricultural Stewardship Association, whose members include organic practitioners although it is devoted

primarily to a broader range of sustainable agriculture issues. Similar developments are occurring in many states, and several universities now have programs or even institutes for sustainable agriculture.

The current focus on sustainable agriculture has been both good and bad for organic agriculture. On one hand, it has diluted the attention that organic agriculture would have received. One the other hand, sustainable agriculture is bridging the gap between organic and conventional agriculture, and the groundwork is being laid for insights gained from study of organic systems to permeate the sustainable agriculture movement. While the Report cannot be credited as the only reason for the changes, it had a major impact on USDA and the land-grant institutions.

Scientific Implications of Organic Farming

The report concluded that:

> There are detrimental aspects of conventional production, such as soil erosion and sedimentation, depleted nutrient reserves, water pollution from runoff of fertilizers and pesticides, and possible decline of soil productivity. If costs of these factors are considered, then cost comparisons between conventional (that is, chemical-intensive) crop production and organic systems may be somewhat different in areas where these problems occur. (p. xiii)

Several recent studies have shown that this conclusion is correct (Faeth, 1993). There also has been a resurgence of activities concerning soil quality, particularly on the potential positive effects of alternative and sustainable systems (Parr et al., 1992).

Agricultural systems are being driven by ever-higher land and other capital costs toward ever-higher productivity. This means that more nutrients must be moved through the soil to the plant to get higher yields. But in Michigan, for example, farmland is closely coupled to our carefully monitored water resources: our groundwater, our 20,000 miles of slow-moving streams, and our 2,300 miles of Great Lakes coastline. Therefore, when we increase nutrient flows, they must be contained much better, because we are not even close to being in equilibrium with our groundwater. One-fourth of our rural wells will have undrinkable water by the end of the decade, and 15% already have about 10 ppm nitrate-N.

Therefore, we must look for a different model of soil nutrient processes. Soil ecologists have much to contribute. Their hypothesis (why didn't we think if it?) is that substrate diversity is what drives soil biological activity ("feeding the soil?"). Earthworms may be leading us astray when we look at basic processes. They are important, but they are at too high an ecological level. Rather, we need to look at microbial populations (Visser and Parkinson, 1992). By putting diverse substrates into the soil through diversified rotations and cover crops or through use of manure or compost, one can manipulate nutrient flow through changes in soil flora and fauna; this in turn explains the 60 to 70% higher level of microbial biomass in the soil in a highly structured, diverse, organic system. In the Rodale Long-Term Farming Systems Trial, for instance, the soil microbial community not only was 80% bigger than in conventional plots, but contained 5.7% of soil nitrogen compared with 3.5% in the conventional plots (Harris, 1993, p. 35). Furthermore, that kind of diversity lays the groundwork for pest and disease management.

Thus the whole system starts to come together once one focuses on getting that extra 1 or 2% of organic matter into the labile phase, and soil quality falls into line. This past summer, for example, we went across a dozen pairs of farms, some organic, some not, along an 800-mile transect in Michigan. We looked at high crop diversity versus monoculture corn. Without exception, whenever there was a high diversity of substrate because of diverse crops or because manure or compost was being applied, there also was high biological activity by two or three different measurements.

This is very exciting as a unifying concept, if it works. It is interesting that the study team articulated the concept, but the times weren't right and not enough scientific data were available to begin to understand what organic agriculture was saying in 1980. The question for today is, if the concept is correct, how sensitive to disruption are the soil effects of diversity and organic management? Can we add nutrients to the system without disrupting it, and what form should they take? This begins to lay the scientific groundwork for communication between different schools of thought.

The sustainable agriculture movement has set the stage for people to look seriously at such concepts. Today there is much less of a gap between organic agriculture and "scientific" thought as we traditionally know it. I am greatly excited and encouraged by this, but I am not pleased that we scientists have not done better in defining the concepts of organic agriculture. It has already taken 10 to 15 years, and it will probably take 10 or 15 more years before we have a truly valid assessment of the points so well articulated in the USDA's Report. That is not something we can be proud of, but we are making progress. We need both the foresight and the courage that Bob Papendick, Jim Parr and the study team showed in determining to study and to understand organic agriculture.

References

1. Faeth, P. 1993. Evaluating agricultural policy and the sustainability of production systems: An economic framework. J. Soil and Water Conservation 48(2):94-99.
2. Harris, G. 1993. Nitrogen cycling in animal-, legume-, and fertilizer-based cropping systems. Ph.D. Dissertation. Michigan State Univ., East Lansing.
3. Klepper, R., W. Lockeretz, B. Commoner, M. Gertler, S. Fast, D. O'Leary, and R. Blobaum. 1977. Economic performance and energy intensiveness on organic and conventional farms in the Corn Belt: A preliminary comparison. Amer. J. Agric. Economics 59:1-12.
4. Lockeretz, W., G. Shearer, R. Klepper, and S. Sweeney. 1978. Field crop production on organic farms in the Midwest. J. Soil and Water Conservation. 33:130-134.
5. National Research Council. 1987. Regulating Pesticides in Food: The Delaney Paradox. Board on Agriculture. National Academy Press, Washington, D.C.
6. National Research Council. 1989. Alternative Agriculture. Board on Agriculture. National Academy Press, Washington, D.C.
7. Parr, J.F., R.I. Papendick, S.B. Hornick, and R.E. Meyer. 1992. Soil quality: Attributes and relationship to alternative and sustainable agriculture. Amer. J. Alternative Agric. 7:5-11.
8. U.S. Dept. of Agriculture. 1980. Report and Recommendations on Or-

ganic Farming. U.S. Govt. Printing Office, Washington, D.C.

9. Visser, S., and D. Parkinson. 1992. Soil biological criteria as indicators of soil quality: Soil microorganisms. Amer. J. Alternative Agric. 7:33-37.

Revisiting the USDA reports: Some additional observations

Robert Papendick

As someone who was very much involved in the organic farming study, it is interesting for me to look at the study 13 years later in relation to where agriculture stands today. I think that both the organic farming and the structure of agriculture studies have had a major impact on agricultural policy, and that Secretary Bergland should be commended for having had the foresight and courage to commission them.

He also contributed in an important way to the substance of the organic farming study. When the team was convened by the USDA, we were given the impression that this was to be a "quick and dirty" study that would be completed in just a few months. However, the team consensus was that we should either do a comprehensive study or not do it at all. A major element of the project was the on-farm case studies of organic farms. The team's plan to do them was strongly encouraged by Secretary Bergland, who had an organic farming neighbor near his home in Minnesota whom several of us visited almost immediately after the team was formally organized. The Rodale Research Center also strongly urged that farm visits be a main part of the study's approach, as Dick Harwood has mentioned.

Several activities took place after the report was published by USDA in 1980. Anson Bertrand, who at the time was director of USDA's Science and Education Administration, decided that after the report was completed we should take it to the field to obtain responses from the public. Several members of the team conducted one-day seminars at four locations: Durham, New Hampshire; Lincoln, Nebraska; Sacramento, California; and Seattle, Washington. The audiences, which averaged about 150 to 200 people, were very diverse, including farmers, researchers, research administrators, extension people, environmentalists, and so forth.

Besides reviewing the public concerns that led to the report and presenting its findings and recommendations, we also solicited the audience's ideas to help us make plans for future research and education on organic farming. The responses generally were very positive, and we received excellent feedback at all the seminars.

My job at these hearings was to give an overview of the report. First, I discussed concerns with agriculture at the time: uncertain availability of energy; heavy dependence on fertilizer inputs; declines in soil productivity; pollution and environmental hazards; health hazards from pesticides; and the demise of the family farm and of local marketing systems. In discussing today's concerns, I could use the same slide I used then, without having to modify it very much, if at all.

Another topic we discussed was why the farmers we visited farmed organically. Their leading reason was concern for soil health, or soil quality, as we would say today. They also were concerned about the effects of farming on human and animal health and the risks to farm workers and to themselves. Protection of the environment generally was the next most important reason. Soil and water conservation and improved food quality also were high on the list of concerns. The organic farmers' motivations corresponded closely with the public concerns mentioned earlier as among the reasons for conducting the study.

We also discussed our definition of organic farming, which called for an ecologically and biologically driven type of agriculture, in contrast to the chemical, high-input type that had been evolving over the past several decades. The alternatives included use of crop rotations, residues, and biological pest controls, among other techniques. We tried to place organic farming on a spectrum of agricultural systems extending from the conventional methods used by most farmers. We considered organic farming to be a range of practices, not a specific, fixed set. Fundamental in this concept was the idea that we should explore ways in which organic practices could be used to reverse agriculture's increasing dependence on chemicals for supplying nutrients and controlling pests.

Many people did not like the word "organic," so we sought other terms as substitutes, such as alternative agriculture and low-input agriculture. "Low-input" emphasized the use of on-farm resources for both crop and livestock production. Low-input methods rely on a holistic approach for the production of food, feed, and fiber. This includes the use of crop rotations, recycling, and appropriate biological cycles and controls to supply plant nutrients, control pests, and minimize the use of external production inputs.

However, the concept of "low-input" never became very popular either, so we sought a term that would have wider acceptance: sustainable agriculture. The 1990 farm bill definition of sustainable agriculture emphasizes integrated cropping sys-

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tems, on-farm resources and biological controls, much like the definitions of low-input and alternative agriculture.

Congress established sustainable agriculture as a national policy goal in the 1985 and 1990 farm bills. These bills were among the first to give agricultural policy a future purpose and direction that addresses many of the undesirable environmental and social consequences of our conventional high-input, highly industrialized agricultural systems, such as soil erosion, water and air pollution, and heavy dependence on chemicals, with their potential threats to the health and safety of farm workers and consumers. The organic farming study showed the nation that we do have alternatives to our current agricultural practices that can help solve these problems, alternatives that will improve agriculture's environmental performance and economic stability, make it more self-sufficient, and reduce or eliminate the health concerns associated with the production of food.

The policy of sustainable agriculture instituted by Congress is still at an early stage of implementation. One outcome of the 1985 and 1990 farm bills are the Sustainable Agriculture Research and Education and the Agriculture in Concert with the Environment programs. Both are funded at very low levels, but they are positioned to develop further the concept and goal of sustainability as a model for agriculture in the future.

A problem we are facing, however, is how to determine with credibility which farming practices contribute to sustainability and which do not. What can we use as a barometer of sustainability? Ideally the barometer should be easy to use, and it should forecast far in advance how a given management system or change in management system will affect productivity, environmental performance, and human and animal health.

One emerging approach for measuring sustainability is soil quality, defined as the capability of a soil to produce an abundance of safe and nutritious crops over the long run and to enhance the health of humans and animals without impairing the natural resource base or harming the environment. A major conference on this subject, entitled "The Assessment and Monitoring of Soil Quality," was held in July 1991, sponsored by the Rodale Institute. (The papers from this conference were published in *American Journal of Alternative Agriculture*, Volume 7, Nos. 1-2, 1992.)

The conference concluded that soil quality should be considered the main key to agricultural sustainability because the soil is fundamental to all ecosystem processes. The definition of soil quality implies that the soil must perform three functions, which are concerned respectively with productivity, the environment, and health. Notwithstanding the many other dimensions of sustainability — economic, cultural, social, and so forth — if the soil's quality cannot be sustained in a given production system, agriculture cannot be sustained, and the other issues become academic. Alternative agriculture is the strategy by which we achieve the goal of sustainability. The components of alternative agriculture — skilled management, crop rotations, organic recycling, reduced chemical systems, integrated crop/livestock production systems, integrated pest management, and so on — all lead to sustainability through their effects on the soil's ability to perform its three key functions. Today, several research efforts are underway to develop an index of soil quality to guide us in developing sustainable agricultural practices. I believe that if this can be achieved, it will go far in the development of farm policies that will promote the concept and goals of sustainable agriculture.

Revisiting the USDA reports: Context, capital and organization

Cornelia Butler Flora

Diversity and Context in Agriculture

Much of what has been said regarding the two USDA reports relates to social organization: How do we organize science? How is indigenous knowledge organized? How is our food system organized? Social organization implies we have choices: at the individual level, the household level, the community level, the regional level, and the national level. It also means we must be aware of the global context in which our actions occur. Social organization is context-specific; one size does not fit all.

So, too, in agriculture. The essence of sustainable agriculture, as Dick Harwood made very clear, is diversity. This means not just diversity of crops and soils but also diversity of people who farm. It means we will have different ethnic groups and both men and women in farming. Farmers with different backgrounds will farm differently. Communities must be diverse enough to offer the alternative services to support different agricultural systems. The single grain elevator to which everyone brings their wheat no longer will work for sustainable agriculture — we will have to diversify our distribution and marketing systems.

But against the importance of diversity is the tendency of science to look for what Kloppenburg (1991) calls the "mobile immutables," the things that are true everywhere, at every time. Science discovers

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those mobile immutables and tries to apply them to agriculture. But when we assume that science consists only of mobile immutables, we are rejecting indigenous knowledge systems, which by nature are contextualized, and we ignore the fact that agriculture, of all the applied sciences, is most context-dependent. We must understand that agriculture's context is a product of both local and global forces, political as well macroeconomic and ecological.

Perhaps we need to look instead for "immobile mutables" that relate variables to each other at a given time and a given place. Can they be "science?" If not, can there be an interchange between science and indigenous knowledge, given that applied science believes that what happens at one point might be repeatable at some other time, given similar conditions? How do we go about fostering such an interchange?

We must move from a reductionist, controlling science toward one that seeks first to understand, and then to control. That is why we must be careful when we hear the demand for long-term research with formula funding. At experiment stations in this country, "long-term research" may just be an excuse for people to keep doing what they have always been doing, but with the word "sustainable" in their CRIS report. Yes, long-term research is needed, but it must be *accountable* long-term research that eventually can be applied. Otherwise we are letting our symbols be used against us.

In organic farming, indigenous knowledge is very important along with scientific knowledge, as Dick Harwood stressed. Indigenous knowledge is what people understand about what they are doing and why they do it. It is important for them to understand that, but just as science is contextualized, so too is indigenous knowledge. In my studies in the Great Plains, I have seen two kinds of farmers: those that work with nature and those that attempt to overcome it. One of my students with an agricultural background pointed this out very well when we brought a sustainable agriculturalist in to talk on the farm crisis some six years ago. Hearing him talk enthusiastically about his soil and about his farm, the student said "He *loves* his soil — he really likes it! Everybody at home hates it. It blows, they can't stand it — they just want to control it."

There are different kinds of indigenous knowledge. We choose among them based on a larger value system. It is important not only to understand the differences but also to appreciate where they come from, and why. We must understand the larger context that makes some people hate their soil, regarding it as an enemy to be overcome rather than a friend to work with. Part of that context is policy, part of it is institutions, and part of it is community and value structures. All of these are mutables. They all can change through concerted action.

Agricultural Structure: More than Land Ownership

A Time to Choose focused on land ownership and the factors that encouraged or discouraged it. As a sociologist, I am worried about viewing the structure of agriculture only in terms of who owns the land. Not that land ownership is unimportant, but profits can move from one area to another regardless of who owns the land. The Mexican *ejido* system of land held in common by small farmers showed how easy it was to extract wealth from presumed landowners (Esteva, 1983). A poultry integrator understands that even if you own the land and buildings and pay the debt on them, the profits they produce with your labor may go somewhere else. Unless we look systematically at flows of all resources instead of just at land ownership, and unless we stop viewing the high price of land or the lack of cheap credit to buy land as *the* problem in agriculture, we are accepting a false picture of the structure of our food system.

Those of us who work in developing countries have learned that cheap credit often is a favor to no one because it encourages risky investment. For U.S. farmers during the 1980s, cheap credit proved to be a good way to lose land because they bought land and equipment that didn't "cash flow" (Barlett, 1993). Cheap credit leads to overcapitalization in agriculture, exactly what happened in the 1970s. By encouraging people to invest in capital-intensive technologies, it makes them focus on single solutions to complex problems.

When we work with whole systems we know that there never is a single solution to a single problem and that each "solution" can bring a new set of problems. The focus on technology as a solution promotes a simplistic, reductionist view of the production and distribution of food and fiber.

But there still is a need for capital. What we have found in developing countries, and what our innovative colleagues who are working with small farmers in the South are finding, is that farmers need small amounts of flexible credit at market rates. They probably won't get that from their local bankers. Local banks may be tied to national or international structures which give loans based on highly formal criteria that reduce the bank's risk. As a result, the bank remains ignorant of new enterprises or new forms of production. Alternatively, local banks may be tied to government loan guarantees that support loans for traditional crops grown in traditional ways. For example, the Farmers' Home Administration does not support rotating loan funds that might be used to supply small amounts of credit for farmers wanting to innovate. Typically, the "pretty paper" — the neat lists of assets and liabilities projected into the future — is what gets the loan. Traditional lenders make loans that are safe. "Safe" means what has been done before, but what has been done before will not support sustainable agriculture.

Thus the problem is not the lack of credit to acquire land or agricultural equipment, nor even the high cost of credit. The problem is the lack of credit that gives farmers more control of the production, processing, and distribution.

Diversity among Grass Roots Organizations

The organic farming and the structure reports stemmed from social movements. They were a response not only to good ideas in the heads of administrators but also to the social environment that said "we have to know this." It is interesting to look at the groups that should be the leaders in this, and in fact are, namely the farmers' organizations.

I am involved in research in which we collaborate with farmers' organizations to examine how sustainable systems affect the farm and the community, both agroecologically and socially. In the four states where I am doing field research — North Dakota, Montana, Minnesota, and Iowa — I have observed four different types of organizations with different goals. If we are to be effective, we must understand the roles of these different kinds of organiza-

tions and the ways that they might become more multipurpose.

The Practical Farmers of Iowa are creating an indigenous knowledge base and documenting it. They are superb in collecting valid data on which practices are more sustainable under what conditions. It is important to be able to say "I used to farm chemically. Now I'm farming organically. I'm making just as much money, and here are the figures that show it." If an alternative system is profitable, it is important to be able to validate it to the people who care about the real family values — money and health.

Another important role of farmers' groups is to influence policy. Here I regard the Alternative Energy Resources Organization in Idaho and Montana as very important in identifying policies that link farming to the environment and in organizing to influence them.

A third role of grass roots organizations, one played by the Northern Plains Sustainable Agriculture Society, is to provide a philosophical base. This forces us to examine why we think the way we do, shows us the linkages between sustainability at different levels, and gives us a framework for addressing sustainability.

Finally, it is necessary to work on the farm to build a locally-based movement that supports farmers in making the transition to sustainable systems and helps them feel they can have control over what they do. The Land Stewardship Project in Minnesota has done this. It has taken a very proactive view of organizations. How do you organize at the grass roots level? How do you take tactics developed in cities, where everything is very confrontational, and use them in the Great Plains, where it just isn't *polite* to confront your neighbor, even one whose dust is blowing all over your field? The members have developed important mechanisms for coopting conventional farmers by picking out one practice that each is doing sustainably and then integrating them into neighborhood-based groups where they in turn will learn from other farmers.

It is important that we in the academic community understand all these roles of grass roots organizations, and that we figure out how to be supportive and responsive. We also must make the enormous leap from being the experts to being the learners. At that point we can move toward a sustainable food and agriculture system.

References

1. Barlett, P.F. 1993. American Dreams, Rural Realities: Family Farms in Crisis. Univ. of North Carolina Press, Chapel Hill.
2. Esteva, G. 1983. The Struggle for Rural Mexico. Bergin & Garvey, Publishers, Inc., South Hadley, Massachusetts.
3. Kloppenburg, J., Jr. 1991. Social theory and the de/reconstruction of agricultural science: Local knowledge for an alternative agriculture. Rural Sociology 56:519-548.

Revisiting the USDA reports: Further thoughts

Paul Johnson

I was down on the farm when the Bergland reports on organic farming and the structure of agriculture were released. I thought at the time they were a "breath of fresh air." At last we were having a national dialogue on how we should farm and who would farm. I was very disappointed in 1981 when this dialogue seemed to come to a screeching halt. It had been so refreshing to watch people get involved in these important issues.

In 1989, I was asked to review the National Academy of Sciences' *Alternative Agriculture* report. As I worked on that report, I couldn't help being reminded of the two Bergland reports. If only the public dialogue could have continued.

When *Alternative Agriculture* was released, like the Bergland reports, it set off a storm of protest and reaction from some sectors of the agricultural community. Fortunately, this time the discussions continued. There are signs that the Department of Agriculture again is opening its doors to alternative ideas.

To be sure, the past five years have seen some progress. We have become more sensitive to connections between agriculture, natural resources, and the environment. Farmers have often needed encouragement from outside agriculture and the changes that have occurred have caused some pain, but I believe they have been healthy.

Unfortunately, we still have not been willing or able to deal with the structure issues. Making changes in *how* we farm the land has been easy compared with decisions on *who* will farm the land. The discussions that took place with the Bergland report on the structure of agriculture need to be revived.

As we talk about the future of American agriculture, let's encourage others to join in. There are many good ideas out there that need to be heard. The National Research Initiative has the potential to do this. I hope it will provide the incentive for disciplines not normally associated with agriculture to become part of the problem-solving process.

This symposium represents a continuation of the national dialogue that began with such promise more than a decade ago. Let us make sure that the dialogue remains vigorous and open to all.

Paul Johnson was a farmer in Decorah, Iowa, and a former member of the Iowa legislature. Recently, he was appointed Chief of the Soil Conservation Service, USDA.

National policy options and strategies to encourage sustainable agriculture: Lessons from the 1990 farm bill

Kathleen Merrigan

History is the greatest teacher of all. As a first step in determining policy options and strategies to encourage sustainable agriculture we should look back and evaluate the past. A review of the 1990 farm bill debate provides six important lessons to guide our future efforts in sustainable agriculture. These lessons can be spelled out this way: Representation; Exhaustion; Frustration, Organization; Retirement; and Mistakes — in sum, *REFORM.*

By ***representation*** I mean the image that most people conjure up when they hear the term "sustainable agriculture". The 1990 farm bill taught us that images are very powerful — and the wrong images can be deadly. Despite Senator Kerrey's (D-NE) eloquent assurances at an early agriculture committee meeting that sustainable agriculture is no longer "hippie-dippy" farming, the predominant image among our congressional representatives continues to be just that: self-proclaimed organic farmers selling vegetables at roadside stands, turning back the clock, going back to the mule, farming as a hobby rather than to make a real living, and so on. Consumers have a different image — they do not differentiate "organic," "sustainable," and "conventional" farming. It is all just farming, and the predominate images are subsidies and handouts, abuse of chemicals, and inhumane treatment of animals.

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Even the advocates of sustainable agriculture promote conflicting representations of it. This lack of a single, unifying image caused many problems in the 1990 farm bill — a prime example being the infamous Senate floor debate over the LISA program (now SARE). When Senator Grassley (R-IA) proposed deleting much of this popular program, a handful of Senators stood up in its defense. But it was clear that no one fully grasped the meaning or definition of sustainable agriculture; Senators on both sides were grappling for ways to express their vague notions of what was important. Add to this the apparent confusion of the media when it came to representing sustainable agriculture. With a few exceptions, reporters did not present a clear image for their readers and viewers; as a result, the public did not engage in the debate. Compare this to the powerful image conjured up when we talk about the "circle of poison." The pesticide activists wisely chose this powerful image to sum up a complex pesticide issue, thereby allowing a wide range of people to understand its importance, and generating thousands of letters to Capitol Hill.

Exhaustion occurred because of how hard we had to work; 14 of the 25 titles in the farm bill, and more than 160 pages, deal directly with natural resource conservation, environmental protection, or consumer issues. We were ambitious and it paid off — at least for a while. Unfortunately, after the bill became law, we were too tired and in many cases too underfunded to carry through on our agenda to ensure that USDA implement these 14 titles and that Congress provide the necessary resources.

The process is never-ending, and it takes place in many policy arenas. How can we sustain an effort that can compete with those of the National Cotton Council, the Rice Millers Association, and similar well-funded groups? Part of the lesson here is that the agriculture committees of Congress are not the only places that matter — other congressional committees play a role and we need to cover them. It is even more difficult when battles over implementation are fought behind the scenes at USDA where grassroots power — the strength of the sustainable agriculture movement — is neutralized.

Let's be honest in retrospect. Despite our arduous efforts, the LISA program was not significantly expanded under the farm bill. The Integrated Farm Management option uses very loose definitions, and it appears that USDA will not implement a program on the scale we had envisioned. The Water Quality Incentives Program is much too small because of funding decisions made by the appropriations committees. Some of our actions even backfired and created more work for us. We thought we were changing the commodity programs fundamentally; the big word was "flexibility." But flexibility did little more than give us more erosion and a few more soybeans. Our work has just begun.

Frustration was what we all felt as we faced a large network of effective lobbyists in Washington who represent conventional agriculture. These lobbyists challenged sustainable agriculture whenever possible.

Their opposition was a great disservice to their clients. I have found that most farmers agree with the basic elements of sustainable agriculture and appreciate its importance to rural communities; most farmers are our friends, provided we can show them how they can make a living and keep their families on the farm. Farmers do not want to spend more on inputs than they have to, and they do not want to contaminate the groundwater their families drink. But there is a striking gap between what farmers believe and what their Washington lobbyists do. It is not in the lobbyists' interest to make peace with sustainable agriculture advocates or to incorporate sustainable agriculture goals into farm programs. Rather, their goal is "billable hours," a goal met by fueling the debate between sustainable and conventional farm interests regardless of the effects on rural America. Looking back, I think we spent too much time being nice, finding common ground, and modifying our views to meet the comfort zone of these disingenuous Washington lobbyists.

Organization refers to the lesson of the 1990 farm bill that puts joy in my heart; coalitions work! The organic certification legislation was important far beyond the issue of certification, because it had a profound and lasting effect on how we make decisions. In a recent national dialogue on sustainable agriculture, a recurrent question was "Who is missing? Whom do we need to bring into our coalition?"

During the organic farm bill debate, environmental groups, consumer groups and progressive farm groups worked hand in hand, with some labor and social justice groups as well. As you might expect, these groups are natural allies, although even such good friends must work out their differences. For example, when I first tried to enlist the expertise and support of consumer and environmental groups regarding organic certification, their reaction was that these things were not on their agenda. Eventually it all clicked, but many agendas remain that would benefit from joint action. For example, the environmental groups were left alone to work out the biotechnology risk assessment program. This was an excellent but undervalued effort to look proactively at the environmental risks posed by these new technologies. Unfortunately, the progressive farm groups passed up the chance to enrich the debate.

Retirement is what happened after the farm bill passed. Sustainable agriculture advocates assumed they could take a break before the 1995 farm bill. But let me warn you: there will likely be several *de facto* farm bills before 1995. Several forces outside the farm bill are driving the policy apparatus. The budget situation will force several key decisions very soon. We have a new administration that wants to leave its mark. Meat inspection is a controversy; restructuring of USDA is under discussion; NAFTA and GATT are pending; a debate is brewing on reauthorization of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and the Administration has announced that rural development is a top priority. What do we do to bring sustainable agriculture into all these new areas, and when do we begin? Clearly, we cannot afford to wait until 1995.

Mistakes offer the most painful lessons. Frankly, we were very lucky in the 1990 farm bill; there is no list of mistakes to review. But it easily could have gone the other way. Often we bluffed and got away with it. We debated on the basis of instinct and beliefs rather than hard cold facts. Unfortunately, we are dealing with great knowledge gaps in sustainable agriculture, and we had better begin to face this reality. My message here is "data, data, data."

How do we obtain this necessary knowledge — the data to bolster the arguments we know in our hearts to be true? Some of it is out there waiting to be reaped. Developing scientific support for our arguments takes time, but we can improve our knowledge in the policy arena immediately. We can become better read for example. Many lobbyists with whom we compete read *Pesticide and Toxic Chemical News*. This weekly publication reports on everything going on at EPA — it is a must for anyone involved in the pesticide debate. But it costs more than $800 a year, so I am not suggesting that we all need to subscribe. But many libraries carry it, and organizations can find ways to share it; a friend sends me his discarded copies. Sustainable agriculture and organic farming interests have good publications too, but we also need to be versed in what our competitors are reading.

Let me give another example. At meetings to discuss farm programs, sustainable agriculture advocates did not have the necessary vocabulary to engage in the debate; we sat on the sidelines watching important decisions being made. We were always at a disadvantage in talking about things like "triple base" or "0-92." The commodity people speak a foreign language that too few of us know (I include myself). We need to understand the nitty gritty of farm programs and become real players in decisionmaking.

These, then, are the six lessons of reform from the 1990 farm bill. Overall, we gained ground, but we should not be satisfied with our achievements. The dictionary defines reform as: making better by removing faults and defects; to correct. Reflecting on the 1990 farm bill, I conclude that we cannot correct a system that is wrong at its very foundation. To ensure a healthy and sustainable agriculture in the 21st century, we need to work for more fundamental change.

Our challenge is to apply these six lessons to change the system in its entirety. To do this we need *VISION*; we must Visualize, Identify, Seduce, Infiltrate, Orchestrate, and Nourish our policy efforts.

First, people must be able to ***visualize*** sustainable agriculture. Page-long definitions do not motivate the masses. Even saying "sustainable agriculture" is a mouthful. We need to develop powerful, unifying images that all supporters of sustainable agriculture — consumers, environmentalists, scientists, and farmers — can agree on and rally around. We also need people who can help us develop a media strategy. Maybe we need celebrity spokespeople; it's not my favorite strategy, but it seems to work for other issues. We spend too much time among ourselves refining definitions that are irrelevant if they are not connected to image-building efforts designed to reach millions of people.

We need to ***identify*** key issues on the policymaking agenda and figure out how to make sustainable agriculture part of each. For example, the potential restructuring of USDA presents many opportunities for sustainable agriculture, especially regarding reorganization of the Extension Service. With President Clinton strongly in favor of some kind of national service, we should work the needs of young farmers into it. There is great concern over minor use pesticides; we should find out who is working on this and include sustainable ag-

riculture in the legislation. We also need to identify key players. During the 1990 farm bill debate, we had amazingly few friends in Congress and the Administration, although those we had were dedicated and deserve great recognition. But we need more allies — it is time to begin building relationships for the next round.

Whom should we ***seduce***? We can start with members of the American Farm Bureau Federation, scientific societies, and the National Association of State Departments of Agriculture. We need a bottom-up strategy designed to disable the political elite in Washington — the lobbyists in snakeskin shoes — so that they no longer speak for farmers. Maybe we can borrow a strategy from the business world: service management, cutting out the middle managers between those who deliver the service and the customer.

We need to ***infiltrate*** more organizations to expand our coalition. Part of this is making sure all interests are represented at our table; too often we forget to invite certain groups, like nutritionists and consumer interests. Part of this is to identify the right issues on which to build common ground. For example, at a recent meeting of the Southern Weed Science Society, a member of the Natural Resources Defense Council gave a talk on the importance of research on weed resistance to herbicides. The weed scientists were very appreciative that there was an agenda they could work on together with environmental groups. Efforts to get urban people more involved with agriculture through Community Supported Agriculture is another example of a suitable area for building common ground.

We also need to ***orchestrate*** our efforts better. Like a finely-tuned professional orchestra, we need to be ready to play many pieces at any time and be able to do good sight-reading if necessary. For example, the National Academy of Sciences will be coming out with a study of effects of pesticides on children. No matter what conclusions it offers, the information will be compelling since the study is looking at the problem in a way that has never been done before. Will the sustainable agriculture community be ready to say "Yes, we understand this, and we have an alternative vision to share"? Are we prepared to get into the media with stories on this issue? Sometimes grassroots organizations feel overwhelmed by everything they must do with their limited budgets and staffs. But if we put people in the right seats in our orchestra, with appropriate parts, we can do it. We need to divide up the parts, instead of each organization trying to be its own band.

Finally, we must ***nourish*** the sustainable agriculture debate with knowledge. Our debates must be more rigorous, and we need to get our stories straight because time is running out. We often lament that we will never be able to beat conventional agriculture in the halls of power. But the truth of the matter is that we will not have to — the budget crunch will do it for us. Policymakers will soon seek alternative farm policies to bring about budget savings. We need to be ready to deliver those policies when that time comes. Many of our proposals are built on thin air. A farmer may be able to look at the soil and know that it's healthy, but in these debates we need documentation, we need numbers, we need more science, and we need better policy work. We can not simply say "let's have a pesticide tax" or "let's have a 50 percent reduction in pesticides." Our energy will be wasted if such proposals are not accompanied by solid analysis.

The lessons from our 1990 farm bill reform efforts taught us a great deal. It is time to apply those lessons, to think big, and to act boldly. It is time to construct our vision for the future because "where there is no vision, the people perish."

Concluding remarks

Bob Bergland

Much has been said here about misplaced priorities. I would like to add an example from my own experience. When I was Secretary, I visited the University of California at Davis to review federally funded research. The researchers there showed off a very expensive new piece of machinery developed largely by federal research funds. The machine was designed to pick square, green tomatoes. When I asked "What in the world is this all about?" they explained that we needed to find new ways to eliminate labor. Back in Washington, I asked the same question, and got the same answer.

Reducing farm labor had been the necessary thing to do in 1942, when we had to free tens of thousands of people to take up arms. But in 1979 we were still at it. In these times, circumstances do not require us to find ways to use fossil energy to free massive amounts of human energy to perform some other public function.

The United States now has the most energy-dependent food system in the world, and with the high and rising cost of energy, we must wonder where this will lead us. We tend to brag about our high-powered efficiency, and we are proud to have replaced human energy with oil, gas, and coal. We did this even though there will be increasing pressure on the world's energy base, with energy producers everywhere looking at that very important resource and asking "Why should we squander it?"

In the Rural Electric Cooperatives, we are putting a lot of brainpower — human energy — into what we call "integrated resource management." We are asking "How much money can we spend to subsidize our consumers who are willing to buy more efficient appliances in order to avoid or delay building the next power plant?" Even in the electric utility business, as reactionary as we are, this approach is start-

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ing to take root because our costs are climbing and our customers realize that we must make basic changes in how we do business.

In agriculture, the question for the 21st century will be "How can we produce more and better food, and use less energy in the process?" I realize it is difficult for researchers to change their agenda and that it takes a long time to persuade the public and get the research appropriations changed, but no question is more important.

Part of the high energy consumption of our agricultural system is connected with perishables, such as meat, milk, fruits, and vegetables. These account for about half of U.S. farm income. The animal business these days is almost completely dominated by a handful of large enterprises. Hardly any independent producers are left. My family used to be independent turkey producers in Minnesota. They patronized the hometown facility. That's how it always had been, but about ten years ago they had a choice: join an integrator or quit. They joined an integrator, but most of the others quit. Today, of the more than 2 million farms in the U.S., about 50,000 families and their integrators or corporations dominate the animal business, with their domination increasing all the time. The high and rising dependence on and cost of purchased energy could put this entire sector in jeopardy.

In crop agriculture something entirely different is happening. In eight of the past ten years, the world has produced more cereal than it has used. Everyone has decided to stimulate the production of food in their own land, including the former Communist countries. Mexico has doubled its corn yields in ten years. Irrigation is being used everywhere, and diseases are being controlled everywhere. Yields are increasing because even in developing countries growers have discovered that a high yield is better than a low yield.

During most of the past half century, the United States usually could count on moving its surplus — we could sell whatever we could grow. One might argue about whether the terms were satisfactory, but almost always we could move it. But this started to change in the early years of the Reagan administration. The United States started losing market share around 1982, and our exports dropped sharply. The Reagan response was to increase export subsidies. We invented market loans, export enhancement, and income transfer payments to growers. By 1984, these totaled $29 billion. None of it was paid for; it was all just added to the national debt. This was our attempt to regain market share, which had been lost when countries that had depended on the United States discovered that it was better to grow their own and save hard currency.

We need to take a very hard look at the role of the United States in the world's food system, especially for grains. Our traditional role was to supply food to a hungry world, but increasingly the world is finding ways to take care of its needs itself.

We need to look at whether it makes sense for us to spend money on fertilizers, on pesticides, and on irrigation to grow crops that we have to subsidize to be able to sell. Do we have our head on straight? I don't think we do. We need to look at the world as it really is, and recast our domestic farm programs in light of the world's demands. I think that needs to be done when the farm bill is extended in 1995. That gives us a few years to look at the basic notion that it is always to our advantage to grow a big crop, price it cheap enough, and sell it overseas for whatever we can get for it. This is a losing proposition that makes no sense. But handlers, suppliers, grain companies, ship owners and truck owners who wanted the large volume came out ahead, with grain growers and taxpayers taking the hit. As long as U.S. taxpayers are willing to pick up the tab, the pressure will continue to increase the volume at any cost.

This situation leads me to predict a very exciting time because we will have an opportunity to cause some serious, substantial policy changes. But it will require all the energy and brainpower we can put into it. If worldwide circumstances force the U.S. to cut back its crop production base, which I think will happen eventually, we will have to look at what to do with those resources. Then we can start thinking in a major way about resource management and stewardship.

Farm Profiles Invited

For its new department on alternative agriculture profiles, the *AJAA* welcomes short articles describing farmers who have adopted interesting alternative practices. The articles should include five elements: a brief description of the farm; the problems that made the farmer look for an alternative approach and the reasons why the alternative seemed plausible; a summary of the basic principles behind the alternative (possibly in a sidebar if it interrupts the flow of text); a discussion of how well the alternative has worked; and a discussion of the applicability of the alternative for other farms. The length should be 1500 to 2000 words.

Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the *American Journal of Alternative Agriculture*. Vol. 3, No. 4, of the *AJAA* has a further description of the department (page 188); or query the editor for further information. Send submissions to the Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Letters To The Editor Invited

The *AJAA* welcomes letters, short or long, commenting on articles in this journal or sharing ideas likely to be of interest to other *AJAA* readers. Since our space is limited, we do reserve the right not to publish all letters or, at times, to publish only excerpts from them. To take part in this exchange of ideas, write to: Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

INSTITUTE NEWS

Wallace Institute Urges Research on Ways To Cut Pesticide Use

The agriculture research community should set a goal of learning how to "by the year 2000, grow our food and fiber with half or less than half of the pesticides now used," according to testimony made recently by Neill Schaller, Associate Director of the Wallace Institute, before the Senate Subcommittee on Agricultural Research, Conservation, Forestry, and General Legislation of the Committee on Agriculture, Nutrition, and Forestry. At the oversight hearing on implementation of agricultural research priorities, Schaller said there is a need to defuse the myth that "sustainable agriculture does not lend itself to good scientific research," and honestly recognize scientists who study sustainability.

Dr. Lynch Hired as Wallace Institute Senior Analyst

Dr. Sarah Lynch, a former USDA economist, is now a senior analyst with the Wallace Institute's Policy Studies Program. She will participate with Dr. Kitty Reichelderfer Smith, Director, Policy Studies Program, in the planning, design, and conduct of studies, and in the reporting and outreach of findings from studies conducted under the program. Those studies will assess the implications for sustainable agriculture of alternative policies or policy directions.

Dr. Lynch will initiate a major study of "green payment program" implementation options, which involve supplementing or substituting commodity program benefits with farm income support payments that would directly contribute to agro-environmental quality goals. Dr. Lynch previously was an economist with the USDA's Economic Research Service, Resources and Technology Division; she also was a self-employed consultant and economist, and a graduate research assistant at Cornell University's Food and Nutrition Policy Program. She has a Ph.D. in Agricultural Economics from Cornell University.

BOOK NOTICES

Agricultural Research Alternatives. William Lockeretz and Molly D. Anderson. 1993. University of Nebraska Press, PO Box 880520, Lincoln, NE 68588-0520. x+239 pp. $30 (add $2.50 s&h), hardcover.

An analysis of research strategies especially associated with alternative agriculture, such as multidisciplinary research, ecology as a foundation for understanding and designing agricultural systems, and on-farm and participatory research. To enable the best ideas from alternative agriculture to permeate all spheres of agricultural research, alternatively-oriented or otherwise, the authors propose institutional and policy changes in departmental organization, the professional reward system, funding mechanisms, and agricultural education.

Challenging the Professions: Frontiers for Rural Development. Robert Chambers. 1993. Intermediate Technology Publications. Distributed in the U.S. by Women, Ink, 777 United Nations Plaza, 3rd Fl., New York, NY 10017. xvi+143 pp. $32.50, hardcover; $6.50, paper.

The "challenge" offered by this book is for professionals in rural development to come up with fundamentally new ways of thinking about their field that will enable them to overcome the biases created by their own values and the rigidity that has unnecessarily restricted the available strategies. The author strongly advocates an approach in which professionals learn from the people they are working with, instead of imposing systems that reflect the prevailing distribution of wealth and power.

Crop Evolution, Adaptation and Yield. L.T. Evans. 1993. Cambridge University Press, 40 W. 20th St., New York, NY 10011-4211. xi+500 pp. $95.00, hardcover.

This book reviews the major paths that have been followed, or that may be followed in the future, to develop crop varieties that are adapted to a broader range of conditions, that yield better where they already are grown, or that make more efficient use of finite resources. Research findings are reported from many crops and many regions, both tropical and temperate, in both traditional and industrialized systems.

LETTER

Scientific inquiry versus technology development in agriculture

William Lockeretz and John Ikerd, in separate features in Vol. 8, No. 2 of *AJAA*, presented excellent comments on some challenges facing applied agricultural research scientists. Lockeretz gave a compelling argument questioning the relevance of drawing conclusions based on data with limited verification over various conditions. Ikerd pointed out the differences in how farmers and scientists approach knowledge and risk, even when they apparently are working on the same problem.

In recent years, these and related questions have troubled agricultural scientists. We have been told that we need a new paradigm, that we need new approaches to research, that scientists must have a new regard for indigenous knowledge, etc. Some scientists have coined terms like systems approach, cropping systems research, and participatory research, among others, in an attempt to break out of a traditional research mode that does not seem to meet their needs in promoting development of sustainable agriculture.

I think that these scientists are dissatisfied with the old way of doing science because of a conflict between means and ends. They are trying to use methods developed for *scientific inquiry*, whereas their true objectives would be better served by methods of *technology development*. Scientific inquiry seeks explanation. Technology development seeks invention.

Ikerd's description of the difference between farmers' objectives and those of scientists is correct. Farmers want to invent more productive management systems, while scientists profit only if they can explain, using statistically acceptable evidence, what might cause different management systems to produce different results. Invention is best when it is informed by science (assuming the science is correct), but an inventor may not want to wait for the scientific inquiry to be completed before advancing, and what is scientifically significant is not necessarily of agricultural significance.

If we understand that designing a sustainable agriculture is principally a matter of technological development, we see that the problem Lockeretz poses will persist. When scientists conduct research in cooperation with farmers, the farmers are in the role of inventors. The farmers will be ready to change treatments much sooner than the scientists. The farmer/inventor probably will have little patience to wait for a verified explanation of observed phenomena, except when all ideas on a practical solution to the problem have been exhausted.

Many of us believe that farmer-directed on-farm research helps fill the gap between scientific knowledge and farm practice. In medical terms we could consider on-farm research *in vivo* and experiment station research *in vitro*. Both are useful, but each has severe limitations; the system functions best when each informs the other. Scientists can help farmers by explaining their findings to them, and in turn can learn by observing farmers' results. The scientist is vital to the continued advancement of sustainable production systems. We should not be surprised, however, if some attempts at scientific inquiry on the farm actually impede the farmer's inventive progress.

We will be able to serve farmers better if we recognize that the development of improved farming systems does not require scientific inquiry at every point. Some farming system development projects take a research-and-development approach, rather than the academic scientist's normal research-and-publish approach. In my opinion, these projects will have the most practical and immediate impact on agriculture.

I hope that discussions of our scientific approach to applied agricultural research will consider the possibility that fostering invention is the most direct way to increase the sustainability of farming systems, even at the expense of scientific inquiry.

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Position Available at Prescott College, AZ

Prescott College seeks candidates for a new faculty position in Agroecology and Sustainable Living, to teach courses such as Agroecology; Sustainable Food Production Methods; Land Stewardship Skills; Food, Nutrition and World Hunger; Ecological Design; and Sustainable Community. Preference will be given to candidates with applied knowledge in appropriate technologies, experience in Third World development, and interest in making use of the College's field station in Kino Bay, Mexico.

While the preferred degree qualification is an earned doctorate, applications are encouraged from exceptional candidates with other qualifications such as a Master's Degree and significant non-academic experience. Starting date is August 10; starting salary is $30,000. Send letter of application, unofficial graduate transcripts, and names of three references who may be contacted by telephone to Ms. Tricia Goffena, Assistant to the Dean of the RDP, Prescott College, 220 Grove Avenue, Prescott, AZ 86301.

Infiltration as a tool for detecting soil changes due to cropping, tillage, and grazing livestock

J.K. Radke and E.C. Berry

Abstract. *Soil physical and biological properties often change when different cropping, tillage, or management systems are imposed. Changes occasionally occur quickly, but usually become evident only after months or years. Infiltration rates are affected by several soil properties and may provide the most sensitive indication of changes in soil properties. To evaluate the use of infiltration measurements for detecting changes in soil properties, we conducted infiltration tests on a cropping systems experiment, a tillage experiment, and two beef cattle grazing experiments. In Pennsylvania, significant changes in infiltration rates did not occur until more than four years after converting from a conventional to a low-input cropping system. Infiltration rates were higher on 14th-year no-till plots compared with moldboard plow and chisel treatments in an Iowa tillage study. Earthworm populations and activity were highest in the no-till treatment. Infiltration rates correlated negatively with increased stocking rates in a long-term beef grazing study in Oklahoma. The number of earthworms did not correlate positively with infiltration in this study, suggesting a complex interaction. A short-term study of overwinter beef corn-stalk grazing in Iowa did not show consistent patterns in infiltration rate or other soil properties with different stocking rates. Infiltration appears to be a good indicator of soil structural changes associated with cropping, tillage, and management systems.*

Key words: beef cattle, grazing, cropping systems, soil physical properties, soil biological properties, earthworms

Introduction

Structurally related soil physical and biological properties often change when different cropping, tillage, or management systems are imposed (Abdel-Magid et al., 1987; Chang and Lindwall, 1989; Bruce et al., 1990). Occasionally, changes occur quickly, but usually they become evident over months or years. Soil water infiltration characteristics are closely related to soil structure and may be a good indicator of changes in soil physical and biological properties.

Infiltration of water depends on several factors, including landscape position, soil type, vegetation, management, and antecedent water content. Pore space and pore size distribution affect the rate of water flow, since water flows through open spaces between soil particles. Biopores caused by soil fauna and old root channels, fracture planes caused by tillage, and soil cracks caused by drying increase infiltration by channelling water quickly to lower layers of soil (Bouma et al., 1982; Mukhtar et al., 1985; White, 1986). Infiltration also depends on the water holding characteristics of the soil (Heard et al., 1988). Soil with much of the pore space already filled with water may have a lower infiltration rate than soil with more air-filled pores. Compaction caused by implements and grazing animals increases soil bulk density and reduces infiltration (Abdel-Magid, 1987; Hamlett et al., 1990).

Infiltration also is influenced by tillage. Deep tillage can break up compacted layers and provide new channels for water flow, or it can destroy old flow channels (Mukhtar et al., 1985; Radcliffe et al., 1988). Increased infiltration often is noted in no-till or other conservation tillage systems (Bruce et al., 1990; Logsdon et al., 1993). Earthworm activity often is greater in reduced-tillage systems, and earthworms that produce vertical channels are associated with increased infiltration (Ehlers, 1975).

Soil surface features also influence infiltration. Soil crusting can severely limit infiltration (Freebairn et al., 1989). Cracks in crusts alleviate this problem until the cracks swell shut again. Soil surface roughness can cause temporary water retention and increase apparent infiltration (Sadeghian and Mitchell, 1990). Higher slope can reduce infiltration by increasing runoff. A surface cover of crops or crop residues can help maintain higher infiltration rates by reducing crusting and by temporarily retaining the rain water.

Infiltration rate is associated with and may be a good integrator of several factors associated with "good soil quality" and productivity (Peters et al., 1992). Our objective was to determine if infiltration can be used as a general purpose indicator of changes or differences in soil properties. We examined three management systems expected to induce changes in soil properties: 1) an experiment where two low-input systems were compared to a conventional cropping system (Kutztown, Pennsylvania); 2) an experiment comparing different

Contribution of the USDA Agricultural Research Service. Trade names are provided for the benefit of the reader and do not imply endorsement or preferential treatment by the authors or the USDA.

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tillage systems (Ankeny and Adel, Iowa); and 3) two beef cattle grazing experiments comparing stocking rates on overwinter corn fields (Ames, Iowa) and grass pastures (Ardmore, Oklahoma).

Sampling, Measurement and Analysis Procedures

Several sampling and measurement procedures were similar for all the experiments. We determined soil slopes for the infiltration plots by measuring the angle between two 1.2-m long bubble levels. One level was placed to conform to the average soil surface while the other level was placed on top of the first and held horizontal (level).

We measured cone penetration resistance in kg-force with a Bush Mark-1 recording penetrometer (manufactured by Findlay, Irvine Ltd., Scotland), which recorded 15 measurements at 3.5-cm increments to a depth of 52.5 cm. A 12.83-mm diameter 30 degree cone was used for all penetrations. Cone resistance can be converted to bars by multiplying kg-force by 0.762. Four penetrations were averaged by depth for each sampling site.

We obtained soil samples by manually inserting a 17-mm or 32-mm diameter JMC Backsaver Soil Probe. The soil cores were divided into 0-15 and 15-30 cm sections. Four cores from the 17-mm tube were combined into one sample. Only one core was used per sample for the 32-mm tube. The soil samples were oven dried at 105°C for gravimetric water content and bulk density determinations. Soil samples for biological measurements were taken with a spade or trowel, placed in plastic bags, and stored in a cooler.

We determined residue and plant cover from photographs taken approximately 1 m from and perpendicular to the soil surface. Percent cover was calculated by placing a grid over the photographs and averaging the fraction of the soil surface covered in each square.

We obtained earthworm samples by collecting soil core samples (200 mm in diameter by 450 mm long) with a modified hydraulic sampler. We collected and identified species for all mature earthworms in each sample. Immature earthworms and cocoons were counted and placed in a dark growth chamber at 15°C in a mixture of partially decomposed horse manure, and allowed to mature before being identified (Berry and Karlen, 1993).

Statistics were computed with the CoStat Statistical Software package by CoHort Software for personal computers. All data sets except the Ames, Iowa Beef Farm Paddock study were analyzed using a one-way or two-way analysis of variance (ANOVA) and differences determined by Tukey's Honestly Significant T-Method. Infiltration curves at or near steady state were fit using linear regression. Correlation or stepwise multiple regression analyses were performed on the Iowa tillage and the Oklahoma beef grazing data sets.

Rodale Conversion Experiment

Experimental procedure

In 1981, the Rodale Research Center, near Kutztown in southeastern Pennsylvania, began a comparative cropping systems experiment (Radke et al., 1988; Liebhardt et al., 1989; Radke et al., 1991). Two low-input cropping systems on land that previously had been managed conventionally (a corn/wheat rotation with synthetic fertilizers and pesticides) were compared with a conventional corn/soybean rotation. All cropping systems used the moldboard plow for primary tillage and were based on five-year crop rotations. The low-input systems included legume forages and small grains as well as corn and soybeans. One low-input system (low-input animal, LIP-A) used animal manures for fertility and organic matter. The second low-input system (low-input cash-grain, LIP-CG) relied on legume green manure crops. Row crops in both low-input systems were cultivated for weed control. The conventional system (CONV) received The Pennsylvania State University recommended rates of synthetic fertilizers and pesticides (Liebhardt et al., 1989) and were not cultivated for weed control. The site is composed primarily of Comly silt loam with smaller areas of Berks shaly silt loam and Duffield silt loam (Table 1).

Ponded infiltration (falling head) measurements were made in 1985 as part of a soil fauna study on the plots (Werner, 1988; Werner and Dindal, 1990). Werner measured infiltration on the corn plots monthly from June through November 1985 using a 30-cm single-ring infiltrometer and recording the rate of decrease in water depth. Similar falling head infiltration measurements were made six times from 1988 through 1991 by Rodale Research Center staff using 5 cm of water inside a 30-cm ring. In 1990 and 1991, a constant-head, 15-cm ring infiltrometer was used to measure cumulative infiltration over a 20-minute period. The head (depth of water) was maintained with a Mariotte water reservoir.

Results and discussion

In 1985, Werner (1988) found significant differences ($p<0.05$) in infiltration rates between corn plots in the cropping system treatments (Figure 1) before significant differences in most other physical properties were detectable. The low-input cash-grain (LIP-CG) system had significantly higher infiltration than did the conventional (CONV) system on five of the six sampling dates, while the low-input animal (LIP-A) system was higher than the CONV only for the June and October measurements. Measurements in the corn plots since 1988 have shown consistently higher (although not always significant) infiltration rates in the two low-input treatments compared with the conventional corn/soybean treatment (Table 2). Infiltration rates after 1989 tended to be higher because of a change in the measurement procedures and a different infiltration device. After 1989, infiltration was measured separately in the rows and between the rows with the 15-cm infiltrometer, whereas previous measurements were made randomly with a 30-cm infiltrometer. Only the in-row infiltration data are presented; however, infiltration was significantly higher in-row than between-row because wheel traffic caused compaction and higher bulk densities in some interrows.

The Rodale experiment, as described by Liebhardt et al. (1989) and Radke et al. (1988), showed that four to five years was necessary to convert a conventional cropping system to either of two low-input cropping systems with stable soil properties and crop yields. During this period, the soil's physical, chemical, and biological properties in the low-input systems were reaching a new equilibrium; corn yields, in particular, were lower than for the conventional system. Since 1985, crop yields from the low-input systems have been at

Table 1. Location and dates of experiments, treatments, measurements made, and soils information for the infiltration experiment on the cropping, tillage, and grazing experiments. See text for explanation of treatments and measurements.

Location	Dates	Treatments[1]	Measurements[1]	Soil Names (Soil Classification)
Kutztown, PA	1981-1990	LIP-A LIP-CG Conventional	Ponded Infl	Comly (Fine-Loamy, Mixed, Mesic Typic Fragiudalf) Berks (Loamy Skeletal, Mixed, Mesic Typic Dystrochrept) Duffield (Fine-Loamy, Mixed, Mesic Ultic Hapludalf)
Ankeny, IA	2-15 Aug 1990	Chisel Plow Moldboard Plow No Till Disk/No Till	Rainfall Infl Soil Water Penetrometer Photographs Worm Counts	Nicollet (Fine-Loamy, Mixed, Mesic Aquic Hapludolls) Webster (Fine-Loamy, Mixed, Mesic Typic Haplaquolls) Clarion (Fine-Loamy, Mixed, Mesic Typic Hapludolls) Disturbed (Webster)
Adel, IA	16-17 Aug 1990	South Field (Ladoga) North Field (Nodaway)	Rainfall Infl Soil Water Penetrometer Photographs	Ladoga (Fine, Montmorillonitic, Mesic Mollic Hapludalfs) Nodaway (Fine-Silty, Mixed, Nonacid, Mesic Mollic Udifluvents)
Ardmore, OK	4-7 Mar 1991	High Medium Low	Rainfall Infl Penetrometer Soil Water Bulk Density Texture Worm Counts	Shidler (Loamy, Mixed, Thermic, Lithic Haplustolls) Steedman (Fine, Montmorillonitic, Thermic Vertic Haplustalfs) Lula (Fine-Silty, Mixed, Thermic Typic Argiudolls) Durant (Fine, Montmorillonitic, Thermic Vertic Argiustolls) Minco (Coarse-Silty, Mixed, Thermic Udic Haplustolls)
Ames, IA				
North Field	2-5 Apr 1991	High Medium Low Rotation 1 Rotation 2	Rainfall Infl Penetrometer Soil Water Bulk Density Texture	Webster (Fine-Loamy, Mixed, Mesic Typic Haplaquolls) Canisteo (Fine-Loamy, Mixed [Calcareous], Mesic Typic Haplaquoll Nicollet (Fine-Loamy, Mixed, Mesic Aquic Hapludolls) Clarion (Fine-Loamy, Mixed, Mesic Typic Hapludolls)
Paddock	7 Aug 1991	Open Path	Double-Ring Soil Water Texture	Webster (Fine-Loamy, Mixed, Mesic Typic Haplaquolls)

[1] All measurements listed for a given location were conducted on all treatments, which were distributed across all soil types shown, exce that at Adel, each "treatment" is a particular field, with the indicated soil type; both fields were tilled with a tandem disk. At Ames, t rotation "treatments" were two locations that actually were treated identically.

Table 2. Infiltration measurements in corn plots in Rodale cropping systems experiment.[1]

Cropping System	Previous Crop	Ponded Infiltration Rate (mm/min)					
		Falling-Head			Constant-Head		
		6/23/88	8/18/88	8/28/89	July 90	Sept 90	Sept 91
LIP-A	hay	14.1 b	9.8 a	6.9 a	52.5 b	206.2 a	75.5 a
LIP-CG	green manure	18.8 b	7.6 a	5.3 a	281.3 a	277.4 a	63.3 a
CONV	corn	2.9 a	5.5 a	3.4 a	—	—	—
CONV	soybean	—	—	6.7 a	34.0 b	149.2 b	38.5 b

[1] Measurements made with a 30-cm diameter falling-head, single-ring infiltrometer in 1988 and 1989 and with a 15-cm diameter constar head, single-ring infiltrometer in 1990 and 1991. (Data collected by S.E. Peters and Rodale Research Center staff.) The 1988-89 data we collected at random; the 1990-91 data were collected only in the corn rows. Column means not followed by the same letter are significant different ($p < 0.05$) by Tukey's Honestly Significant T-Method.

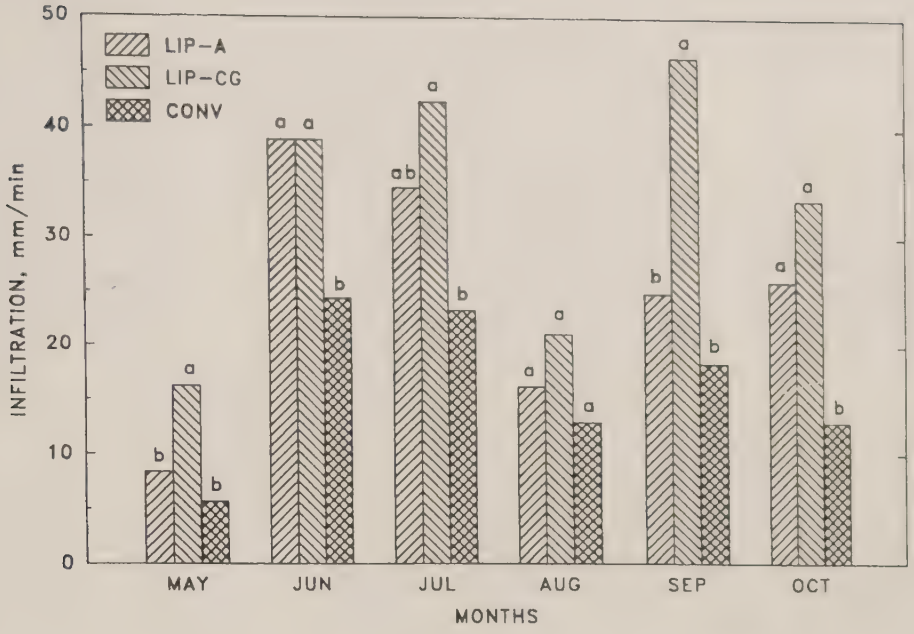

Figure 1. Infiltration rate means for the corn plots in the low-input animal (LIP-A), low-input cash-grain (LIP-CG), and conventional (CONV) treatments of the cropping systems experiment at the Rodale Research Center, Kutztown, Pennsylvania, May through October 1985. Treatment bars within months that do not have the same letter above them are significantly different ($p < 0.05$) by Tukey's Honestly Significant T-Method. (Unpublished data from Ph.D. Thesis by Matthew Werner [1988], used with the author's permission.)

least as good as the yields from the conventional system. Radke et al. (1988) found that water content in the top 30-cm of soil was higher in the low-input system with green manure (LIP-CG) system in 1985. Soil in the low-input plots was more friable and "spongy," whereas the soil in the conventional plots was drier and more brittle (Peters et al., 1992). This qualitative "feel" has been born out by higher infiltration rates in the low-input plots, but other physical measurements, such as bulk density and soil penetrability, show significant differences less often, in part because of large soil variability. In these studies, infiltration was an effective indicator of changes in soil physical properties and biological activity.

Iowa Tillage Study

Experimental procedure

In August 1990 we measured infiltration and earthworm activity on a long-term tillage experiment initiated in 1977 at the Iowa State University Research Farm at Ankeny, and on a separate study at the Gustafson Research Farm at Adel. Continuous corn was grown at both locations. A randomized block experiment with four treatments and four replicates was used at Ankeny. The treatments were Chisel (C), Moldboard Plow (MP), No-Till (NT), and Disk until 1987 but No-Till thereafter (DNT). All tillage was done with a tandem disk (TD) at Adel. Two field plot locations at Adel were being prepared for a future experiment and were not cropped at the time of measurement. The fields (North and South) were managed the same (tandem disk), with the "treatments" being the two locations (soil types), which were not randomized.

We used a simulated rainfall infiltrometer (Onstad et al., 1981) to measure the infiltration characteristics in each of the 16 plots at Ankeny and 8 plots at Adel. All plots at Ankeny were planted to corn in 1991. The corn plants were cut off at the soil surface and removed from the measurement area before the infiltration measurements.

Steel forms were forced approximately 10 cm into the soil on three sides of a 0.92 × 1.52 m test area. A collection trough was placed level with the average soil surface on the downslope 0.92-m end of the plot to funnel the runoff through a tipping bucket water-flow measurement device positioned in a 0.6 × 0.6 × 0.6 m pit. A portable computer recorded the number of tips per minute and the time of each bucket tip. Water from the tipping bucket was pumped into a collection cylinder for further measurement and analysis. The portable rainfall simulator was placed over the test plot and 1.06 mm/min of water was applied for 60 minutes or until steady state infiltration was indicated by the computer display. Soil samples were taken at 0-15 and 15-30 cm next to the wetted test area for gravimetric water analysis. After the test plots had dried sufficiently, 50-cm steel cylinders were forced into the soil approximately 15 cm and then tipped over to break off a 15-cm layer of soil. The diameter of each earthworm hole at this interface was measured with peg gauges and recorded. The total area of the earthworm holes

within the cylinder for the 15-cm depth was computed by summing the areas of the individual holes. Earthworm populations in each of the 16 plots were determined from six subsamples per plot as described by Berry and Karlen (1993).

Results and discussion

Mean cumulative runoff curves from the simulated rainfall at Ankeny show the separation of the four tillage treatments into two distinct groups: 1) moldboard plow and chisel; and 2) no-till (Figure 2). Infiltration rates computed at steady state show that the two no-till treatments (DNT and NT) are different from the moldboard plow (MP) and chisel (C) treatments at $p < 0.05$ (Table 3). Total worm counts taken during the spring and fall of 1990 also were significantly higher ($p < 0.05$) in the no-till compared with the moldboard plow and chisel treatments (Berry and Karlen, 1993). Correlation and multiple regression analyses showed that infiltration was not influenced by slope, antecedent soil water content, or total number of worms in this experiment. However, surface residue cover and total worm hole area in a 50-cm diameter circle at 15-cm depth were highly correlated with infiltration. Infiltration rate plotted against the total pore area of worm holes at 15-cm shows higher infiltration rates and pore areas for the two no-till treatments compared with the moldboard plow and chisel treatments at Ankeny and the tandem disk (TD) treatments at Adel (Figure 3). Infiltration rate at steady state, total worm-hole area, resi-

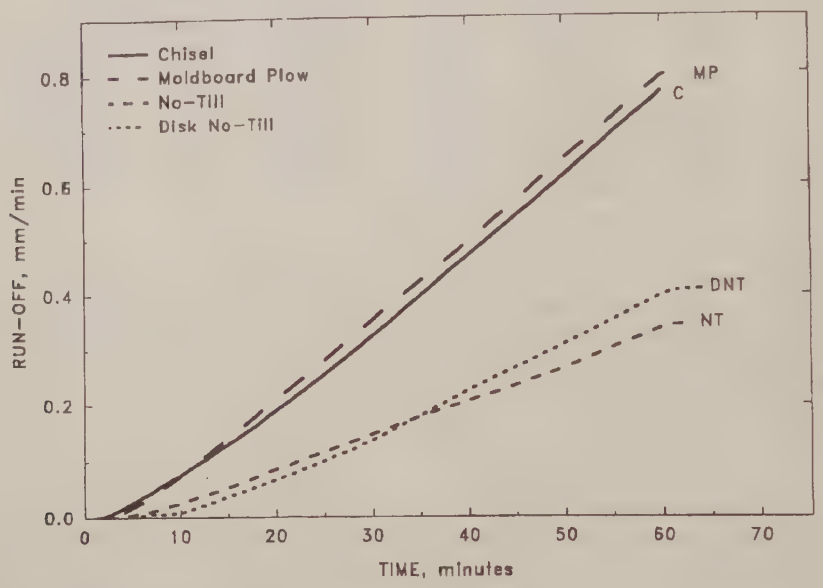

Figure 2. Mean runoff from simulated rainfall for the four tillage plots at Ankeny, Iowa, August 1990.

Table 3. Means and statistical comparisons of the measurements made at the Ankeny and Adel, Iowa sites in 1990.[1]

Treatment	Infiltration Rate (mm/min)	Slope (%)	Gravimetric Water Content (g/g soil) 0 - 15 cm	Gravimetric Water Content (g/g soil) 15 - 30 cm	Pore Area at 15 cm (mm^2)	Cover (%)	Worms (per 6 samples)
				Ankeny			
DNT	2.93 a	1.8 b	0.185 a	0.211 a	563 a	45.5 a	34 a
NT	2.71 a	3.2 ab	0.185 a	0.202 a	597 a	47.7 a	44 a
MP	0.75 b	3.0 ab	0.176 a	0.179 a	370 b	12.3 c	16 b
C	1.27 b	4.0 a	0.184 a	0.210 a	328 b	27.4 b	13 b
				Adel			
TD—North	1.30 a	0.0 b	0.164 a	0.183 a	117 a	2.3 b	—
TD—South	1.07 a	2.0 a	0.164 a	0.177 a	192 a	31.4 a	—

[1] Within a location, column means not followed by the same letter are significantly different ($p < 0.05$) by Tukey's Honestly Significant T-Method. DNT = disk converted to no till; NT = no till; MP = moldboard plow; C = chisel; TD = tandem disk.

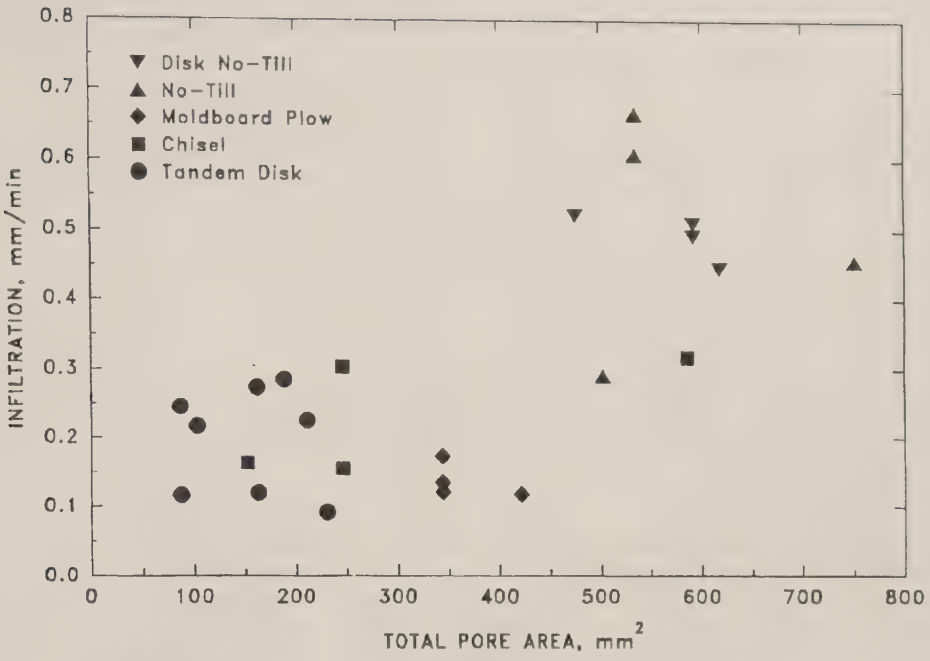

Figure 3. Simulated rainfall infiltration rate versus the total area of earthworm holes in a 50-cm diameter circle at 15-cm depth for five tillage treatments at Ankeny and Adel, Iowa, August 1990.

due cover and total number of worms were strongly related to the tillage treatments at Ankeny and Adel.

The number of worms was higher in the no-till treatments (Table 3) but the amount of worm hole area was more important for infiltration. Infiltration correlated better with pore (worm hole) area ($p < 0.014$) than number of worms ($p < 0.095$). The presence of worms does not guarantee open channels for water flow. Worm burrows may not come to the soil surface or may be covered with worm cast material, or the worm may be in the burrow, preventing water from flowing through that burrow. However, greater numbers of macropores due to worm burrows, old root holes, or cracks in no-till systems have been cited as increasing infiltration (Edwards et al., 1988).

Beef Grazing Experiment at Ardmore, Oklahoma

Experimental procedure

In March 1991, we used the simulated rainfall infiltrometer (Onstad et al., 1981) to measure infiltration characteristics on a long-term beef grazing experiment conducted by the Noble Foundation at a site near Ardmore, Oklahoma. The experiment was initiated in 1987 using a randomized block design with 3 stocking densities as treatments and 3 replicates. Plot size was approximately 2.5, 4.5, and 7.0 ha for the High, Medium, and Low treatments, respectively. Stocking rates were approximately 5.6 (L), 11.2 (M), and 22.5 (H) Mg/ha of beef cattle, which corresponded roughly to 12.5, 25, and 50 cows/ha, respectively. The soils are mostly silt loams with gradations to silty clay loams, clay loams, and loams. The soil series include Lula, Durant, Minco, Shidler, and Steedman (Table 1). We made infiltration measurements on 4-7 March 1991 at 18 locations (two per plot). Simulated rainfall was applied to 0.92 × 1.52 m areas at a rate of 1.06 mm/min for 45 minutes or until steady state infiltration was achieved. We also measured gravimetric soil water contents at 0-15 and 15-30 cm, cone penetrometer resistance measurements to 52.5 cm in 3.5-cm increments, soil slope, and soil bulk density at each location. We counted earthworms from each of the nine plots by taking ten subsamples per plot as described by Berry and Karlen (1993).

Results and discussion

Infiltration rates were significantly higher ($p < 0.05$) for the low stocking rate compared with the medium and high stocking rate treatments (Figure 4). Plots 5, 6, and 7 were located near a hilltop with rather shallow topsoil over calcareous material. These plots tended to have higher soil water content in the 0-15 cm layer (Table 4). Two of these plots (5 and 7) had the Low stocking rate treatment, which skewed the water content for this treatment upward compared with the Medium and High treatments. One location within Plot 6 (Medium stocking rate) was in an outseep area and had a low infiltration rate, which skewed the Medium stocking rate treatment downward. Soil water content was highest and average cone penetration resistance in the top 15-cm was the lowest for this plot. The number of earthworms was low (four per sample), not significantly different across treatments and uncorrelated with infiltration. We found two different species of *Diplocardia*, based on differ-

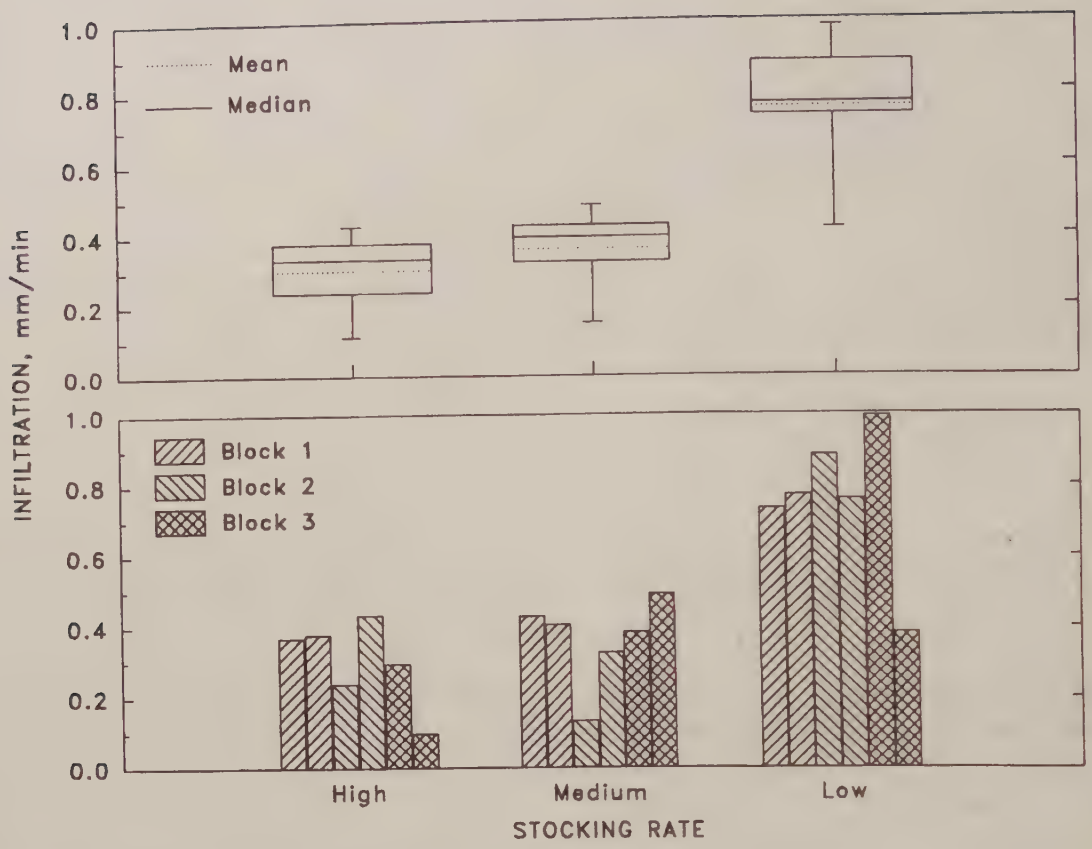

Figure 4. Simulated rainfall infiltration rates for the three beef cattle stocking densities at Ardmore, Oklahoma, March 1991. In the upper portion of the figure, box plot limits represent 25 and 75 percentiles and the error bars represent 10 and 90 percentiles.

ences in size and in feeding and burrowing habits. The earthworms in plots 5, 6, and 7 were very large, approximately 30 cm long, whereas those in other plots generally were 1 to 4 cm long. In the areas with the larger *Diplocardia*, many burrows with surface casts were noted, but none were found in the other areas. Classification of this group is difficult and taxonomic keys are generally unavailable (James, 1990). Little is known about the ecology of the *Diplocardia* group. However, James did report the presence of *Diplocardia* in this area that feed on the surface litter from a home burrow system, similar to the night crawler (*Lumbricus terrestris* L.).

Iowa Beef Grazing Study

Experimental procedure

We made several infiltration measurements at the Iowa State University Beef Nutrition Farm at Ames in fall 1990 and in spring and summer, 1991. Infiltration measurements were conducted at a site used in a controlled grazing experiment on corn residue. We collected additional data on a site used for a controlled grazing experiment on a mixed-grass pasture.

Corn stalk grazing. Recently, ISU animal scientists have been studying the effect of overwinter beef cattle grazing on corn residues left in the field after grain harvest. Concern over potential damage to soil structure led us to do soil tests in fall 1990 and spring 1991. Soils were of the Webster, Nicollet, Clarion, Canisteo series and graded in texture from clay loam to loam (Table 1). We used the same simulated rainfall infiltrometer and procedures described for the Oklahoma studies. We made a series of baseline infiltration and cone penetrometer measurements the first week of November 1990 after corn harvest but before stocking with beef cattle. Stocking densities were 1.2 (Low), 2.3 (Medium), and 4.7 (High) cow-months per hectare, obtained by placing 3 cows (590 to 680 kg each) on 4.8, 2.4, and 1.2 hectares, respectively, for 56 days. At two locations, cows initially stocked at 4.7 cows per hectare were allowed into additional areas every two weeks. The two rotational treatments were intended to be managed differently, but were managed the same in this experiment; therefore, "treatment" in this experiment refers to the two locations.

The cattle were put on the treatment areas the first week in November and removed to another corn field in January. For comparison purposes, two 1.5-m × 1.5-m cages were placed in each treatment to prevent disturbance by cattle. We made rainfall infiltration measurements at two grazed and two caged locations within each treatment on 2-5 April 1991. Soil samples were taken at depths of 0-15 and 15-30 cm for gravimetric soil water con-

Table 4. Means of the measurements made at Ardmore, OK in 1991 for the 18 (H)igh, (M)edium, and (L)ow stocking rate plots, and the means and statistical comparisons of the means for the three stocking rate treatments.

Location/ Treatment	Infiltration Rate (mm/min)	Slope (%)	Penetrometer Resistance (kg/cm^2)	0 - 15 cm Gravimetric Water Cont. (g/g soil)	0 - 15 cm Bulk Density (g/cm^3)	15 - 30 cm Gravimetric Water Cont. (g/g soil)	15 - 30 cm Bulk Density (g/cm^3)	Ergosterol (µg/g soil)	Microbial Respiration[1] (mg C/100 g soil)	Microbial Biomass (mg C/100 g soil)	Worms (per 10 samples)
					Means by Plot						
1A-H	0.37	1.6	19.4	0.193	1.39	0.199	1.66	3.4	30.0	17.1	34
1B-H	0.38	0.7	20.3	0.169	1.18	0.184	1.64	2.9	18.8	8.5	
2A-L	0.73	1.0	19.0	0.196	1.06	0.187	1.60	3.3	26.3	12.5	35
2B-L	0.77	1.0	18.6	0.181	1.11	0.186	1.72	3.2	28.6	10.8	
3A-M	0.43	3.7	16.7	0.196	1.11	0.203	1.41	3.3	29.2	9.1	21
3B-M	0.41	4.7	24.3	0.202	1.10	0.218	1.67	4.5	29.5	8.8	
4A-H	0.24	7.8	20.2	0.194	1.13	0.203	1.43	3.6	28.0	11.9	45
4B-H	0.43	4.4	18.9	0.207	1.11	0.217	1.67	4.7	30.6	10.5	
5A-L	0.88	3.1	19.0	0.222	1.08	0.159	1.50	1.4	34.3	7.8	44
5B-L	0.76	3.1	16.7	0.264	1.20	0.244	1.44	2.2	38.1	10.5	
6A-M	0.13	7.8	10.9	0.293	1.21	0.269	1.56	1.1	27.7	12.9	43
6B-M	0.33	7.0	17.2	0.244	1.14	0.232	1.59	3.7	40.3	12.8	
7A-L	0.99	2.1	17.8	0.280	1.02	0.221	1.58	2.0	35.3	13.7	23
7B-L	0.38	1.6	18.4	0.241	1.15	0.230	1.43	3.1	42.7	8.1	
8A-H	0.30	1.8	19.1	0.175	1.43	0.218	1.80	2.8	22.8	7.0	39
8B-H	0.10	4.7	20.5	0.180	1.28	0.218	1.74	2.7	19.9	7.2	
9A-M	0.38	5.7	23.1	0.161	1.35	0.196	1.58	3.0	20.9	5.9	101
9B-M	0.49	9.4	23.7	0.177	1.11	0.210	1.61	4.1	27.0	10.5	
					Means by Stocking Rate[2]						
High	0.30 b	3.5 b	19.7 a	0.186 b	1.25 a	0.206 a	1.66 a	3.4 a	25.0 b	10.4 a	39 a
Med	0.36 ab	6.4 a	9.3 a	0.212 ab	1.17 a	0.221 a	1.57 a	3.3 a	29.1 a	10.0 a	55 a
Low	0.75 a	2.0 b	18.2 a	0.231 a	1.10 a	0.204 a	1.55 a	2.5 a	34.2 a	10.6 a	34 a

[1] Respiration determined from Day 10 to Day 20 of fumigation/incubation procedure described by Jenkinson and Powlson (1976).
[2] Column means not followed by the same letter are significantly different ($p<0.05$) by Tukey's Honestly Significant T-Method.

tent, bulk density, and biological analyses, including ergosterol (a compound associated with soil fungi [Grant and West, 1986]), carbon respiration, and microbial biomass (Jenkinson and Powlson, 1976).

Beef pasture studies. To determine the impact of severe livestock trampling, we conducted an infiltration study on a grass pasture (Webster clay loam, Okoboji silty clay loam, and Clarion loam soil series, Table 1) at the Beef Nutrition Farm at Ames. On 7 August 1991, we measured infiltration with a double-ring infiltrometer along a cow path and in open pasture. Three measurements were made in the cow path at approximately 8, 12 and 21 m south of the watering tank. Three comparison measurements were made in the open pasture 3 m east of each site in the path. The double-ring infiltrometer consisted of a 30-cm inner ring and a 60-cm outer ring. Water was supplied by 3- and 10-liter Mariotte reservoirs equipped with pressure transducers for automatic data logging of

flow rates. Infiltration was recorded for 60 minutes or until the Mariotte reservoirs were empty. Infiltration rate was determined by linear regression from the last, linear portion of the curve of water volume versus time. Soil samples were taken at 0-15 and 15-30 cm for gravimetric and bulk density determinations.

Results and discussion

Corn stalk grazing. Infiltration tests and measurements of other soil properties showed no detrimental soil effects from overwinter beef cattle grazing of corn stalks during the winter of 1990-91. Slope, cone penetrometer resistance, soil water content, soil bulk density, and ergosterol content showed no differences among treatments or between trampled and caged areas (Table 5). Although infiltration was significantly different ($p < 0.02$) among some stocking treatments, with the Medium greater than the Low and Rotation 1 treatments (Table 5), there was no consistent pattern in the relation between infiltration and stocking rate or traffic. Soil respiration ($p < 0.021$) and microbial biomass ($p < 0.012$) also were significantly affected by stocking rate. Respiration was greater on the High than the Low treatment. Biomass was higher on the Rotation 1 than the High treatment. However, none of the above measurements showed any differences between trampled and untrampled (caged) areas.

These findings are not surprising. All stocking rates were low compared with pasture grazing, and the animals were on the fields for only two months during the coldest part of the winter, when the soil was frozen. Had the soil been thawed and wet, the soil might have been damaged by compaction.

Beef pasture studies. Infiltration tests on mixed-grass pastures at the ISU Beef Nutrition Farm showed a potential for soil compaction and structural damage. Infiltration rates were greatly reduced in cow paths closer to the water tank area (Figure 5). Infiltration rates at various distances from the water tank differed significantly ($p < 0.014$), and rates in the path versus open pasture also differed significantly ($p < 0.0009$). Bulk density was greater on the path, and increased nearer the water tank. Soil water content was higher in the path than the open pasture, reflecting the higher bulk density and the lack of vegetation that consumed soil water. Cone penetrometer resistance in the top 15 cm was higher in the path than in the open pasture but was lower at depths greater than 15 cm because of the higher water content under the cow path.

Summary and Conclusions

Water infiltration rates differed significantly among cropping systems at Kutztown, Pennsylvania, among tillage

Table 5. Means and statistical comparisons of the measurements made at the Iowa State University Beef Nutrition Farm near Ames, 1991.[1]

	Infiltration Rate (mm/min)	Slope (%)	Penetrometer Resistance (kg/cm^2)	0 - 15 cm Gravimetric Water Cont. (g/g soil)	0 - 15 cm Bulk Density (g/cm^3)	15 - 30 cm Gravimetric Water Cont. (g/g soil)	15 - 30 cm Bulk Density (g/cm^3)	Ergosterol (μg/g soil)	Microbial Respiration[2] (mg C/100 g soil)	Microbial Biomass (mg C/100 g soil)
	Means by Stocking Rate									
Low	0.596 b	1.2 a	9.2 a	0.227 a	1.28 a	0.244 a	1.32 a	1.08 a	15.9 b	7.3 b
Med	0.871 a	-0.3 a	8.4 a	0.266 a	1.43 a	0.249 a	1.59 a	1.76 a	25.3 ab	10.9 ab
High	0.768 ab	1.3 a	8.5 a	0.283 a	1.35 a	0.265 a	1.47 a	1.42 a	27.6 a	5.8 b
Rot-1	0.576 b	1.6 a	9.2 a	0.232 a	1.51 a	0.256 a	1.63 a	1.71 a	22.1 ab	12.6 a
Rot-2	0.644 ab	1.2 a	8.8 a	0.230 a	1.32 a	0.241 a	1.35 a	1.04 a	16.8 ab	6.2 b
	Means by Traffic									
No cage	0.685 a	1.2 a	9.2 a	0.243 a	1.47 a	0.252 a	1.45 a	1.55 a	21.1 a	8.5 a
Cage	0.697 a	0.8 a	8.5 a	0.252 a	1.29 a	0.250 a	1.49 a	1.25 a	22.0 a	8.6 a

[1] Within each section of the table, column means not followed by the same letter are significantly different ($p < 0.05$) by Tukey's Honestly Significant T-Method.

[2] Respiration determined from Day 10 to Day 20 of fumigation/incubation procedure described by Jenkinson and Powlson (1976).

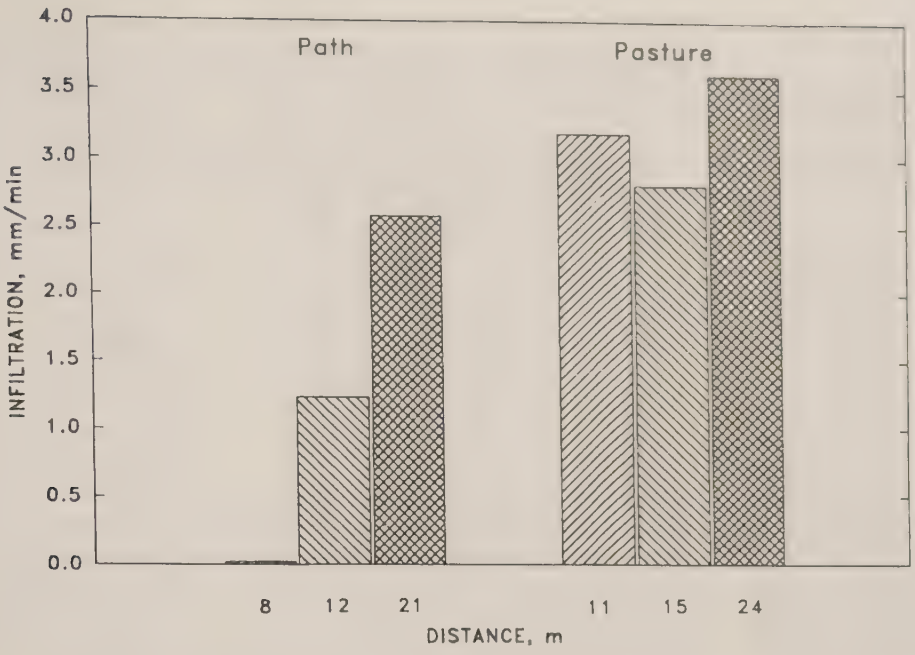

Figure 5. Infiltration rates measured with a double-ring infiltrometer at three increasing distances from the water tank in a cattle lane or adjacent to the cattle lane in the open pasture at the Beef Nutrition Farm near Ames, Iowa, in 1991.

systems at Ankeny and Adel, Iowa, and among stock grazing rates at Ardmore, Oklahoma. These all were long-term experiments with sufficient time for soil property differences to be established. We found no consistent relationship of infiltration rate to stocking rate or traffic in the short-term, corn-stalk grazing study at Ames.

We found infiltration differences in situations where changes in soil properties were expected but were difficult to discern using other physical measurements. There were no instances where differences in soil properties were observed with another technique but not observed with infiltration measurements.

Ponded, falling-head infiltration tests are easy to make and provide good information for comparisons. Simulated rainfall infiltration is more difficult and time consuming, but provides a measurement more closely related to natural rainfall than ponded infiltration measurements. Fewer simulated rainfall measurements can be made in a day than ponded measurements, but the area measured is larger, so that fewer runs may be required. Ponded, constant-head infiltration is relatively easy to measure and may be the best compromise for routine measurements. However, simulated rainfall infiltrometers and ponded infiltrometers do not measure the same response.

We found the ponded and simulated rainfall infiltrations to be good integrators of structurally related soil properties. We intend to use infiltration to learn when changes in soil properties have occurred, and then run other tests to determine the causes.

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References

1. Abdel-Magid, A.H., G.E. Schuman, and R.H. Hart. 1987. Soil bulk density and water infiltration as affected by grazing systems. J. Range Management 40:307-309.
2. Berry, E.C., and D.L. Karlen. 1993. Comparison of alternative farming systems. II. Earthworm population density and species diversity. Amer. J. Alternative Agric. 8:21-26.
3. Bouma, J., C.F.M. Belmans, and L.W. Dekkar. 1982. Water infiltration and redistribution in a silt loam subsoil with vertical worm channels. Soil Sci. Soc. Amer. J. 46:917-921.
4. Bruce, R.R., G.W. Langdale, and A.L. Dillard. 1990. Tillage and crop rotation effect on characteristics of a sandy surface soil. Soil Sci. Soc. Amer. J. 54:1744-1747.
5. Chang, C., and Lindwall, C.W. 1989. Effect of long-term minimum tillage practices on some physical properties of a chernozemic clay loam. Canadian J. Soil Sci. 69:443-449.
6. Edwards, W.M., L.D. Norton, and C.E. Redmond. 1988. Characterizing macropores that affect infiltration into nontilled soil. Soil Sci. Soc. Amer. J. 52:483-487.
7. Ehlers, W. 1975. Observations of earthworm channels and infiltration on tilled and untilled loess soil. Soil Sci. 119:242-249.
8. Freebairn, D.M., S.C. Gupta, C.A. Onstad, and W.J. Rawls. 1989. Antecedent rainfall and tillage effects upon infiltration. Soil Sci. Amer. J. 53:1183-1189.
9. Grant, W.D., and A.W. West. 1986. Measurement of ergosterol, diaminopimelic acid and glucosamine in soil: Evaluation as indicators of micro-

bial biomass. J. Microbiological Methods 6:47-53.
10. Hamlett, J.M., S.W. Melvin, and R. Horton. 1990. Traffic and soil amendment effects on infiltration and compaction. Trans. Amer. Soc. Agric. Engineers 33:821-826.
11. Heard, J.R., E.J. Kladivko, and J.V. Mannering. 1988. Soil macroporosity, hydraulic conductivity and air permeability of silty soils under long-term conservation tillage in Indiana. Soil and Tillage Research 11:1-18.
12. James, S.W. 1990. Oligochaeta: Megascolecidae and other earthworms from southern and midwestern North America. In D.L. Dindal (ed). Soil Biology Guide. John Wiley, New York, N.Y. pp. 357-391.
13. Jenkinson, D.S., and D.S. Powlson. 1976. The effects of biocidal treatments on metabolism in soil. I. Fumigation with chloroform. Soil Biology and Biochemistry 8:167-177.
14. Liebhardt, W.C., R.W. Andrews, M.N. Culik, R.R. Harwood, R.R. Janke, J.K. Radke, and S.L. Rieger-Schwartz. 1989. Crop production during conversion from conventional to low-input methods. Agronomy J. 81:150-159.
15. Logsdon, S.D., J.K. Radke, and D.L. Karlen. 1993. Comparison of alternative farming systems. I. Infiltration techniques. Amer. J. Alternative Agric. 8:15-20.
16. Mukhtar, S., J.L. Baker, R. Horton, and D.C. Erbach. 1985. Soil water infiltration as affected by the use of the paraplow. Trans. Amer. Soc. Agric. Engineers 28:1811-1816.
17. Onstad, C.A., J.K. Radke, and R.A. Young. 1981. An outdoor portable rainfall erosion laboratory. Proc. Florence Symposium "Erosion and Sediment Transport Measurement." International Association of Hydrological Sciences Pub. No. 133:415-422.
18. Peters, S.E., R.R. Janke, and M. Bohlke. 1992. Rodale's farming systems trial 1986-1990. Rodale Institute Research Center, Kutztown, Pennsylvania. 45 pp.
19. Radcliffe, D.E., E.W. Tollner, W.L. Hargrove, R.L. Clark, and M.H. Golabi. 1988. Effect of tillage practices on infiltration and soil strength of a typic hapludult soil after ten years. Soil Sci. Soc. Amer. J. 52:798-804.
20. Radke, J.K., R.W. Andrews, R.R. Janke, and S.E. Peters. 1988. Low-input cropping systems and efficiency of water and nitrogen use. In W.L. Hargrove (ed). Cropping Strategies for Efficient Use of Water and Nitrogen. Special Pub. 51. Amer. Soc. Agronomy, Crop Sci. Soc. Amer., and Soil Sci. Soc. Amer., Madison, Wisconsin. pp. 193-218.
21. Radke, J.K., M.J. Shaffer, K.S. Kroll, and J. Saponara. 1991. Application of the nitrogen-tillage-residue-management (NTRM) model for corn growth in low-input and conventional agricultural systems. Ecological Modelling 55:241-255.
22. Sadeghian, M.R., and J.K. Mitchell. 1990. Response of surface roughness storage to rainfall on tilled soil. Trans. Amer. Soc. Agric. Engineers 33:1875-1881.
23. Werner, M.R. 1988. Impact of conversion to organic agricultural practices on soil ecosystems. Ph.D. Thesis, College of Environmental Science and Forestry, State Univ. of New York, Syracuse.
24. Werner, M.R., and D.L. Dindal. 1990. Effects of conversion to organic agricultural practices on soil biota. Amer. J. Alternative Agric. 5:24-32.
25. White, E.M. 1986. Longevity and effect of tillage-formed soil surface cracks on water infiltration. J. Soil and Water Conservation 41:344-347.

UPCOMING EVENTS

March 1 is the deadline for papers for *Decision Support—2001*, the International Geographic Information and Resource Technology Seminar to be held in Toronto September 12-16; contact Terry Daniel, University of Arizona, Dept. of Psychology, Tucson, AZ 85721; (602)621-7453.

March 2-9, *Ranching for Profit School* will be held in Kerrville, TX; contact Elaine Kelly, Ranch Management Consultants, 7719 Rio Grande Blvd. NW, Albuquerque, NM 87107; (505)898-7417.

March 3-6, *1994 Annual Conference of the North American Deer Farmers Association* will be held in New Orleans; contact Barbara Fox, NADeFA, (301)459-7708.

March 4, *Northeast Iowa Grazing Conference* will be held at Northeast Iowa Community College, Calmar; contact Connie Hvitved, Continuing Education Coordinator, 1-800-728-2256, ext. 219.

March 4-5, *1994 Upper Midwest Organic Farming Conference* will be held at Sinsinawa Mounds, near Dubuque, IA; contact Laura Benson, UMOFC, P.O. Box 159, LaFarge, WI 54639; (608)625-2602.

March 4-5, *Transitions Farmers Conference* will be held in Auburn, N.Y.; contact Judy Green, Cornell University Farming Alternatives Programs, (607)255-4413.

March 7-10, *National Pesticide Management Conference* will be held in St. Louis, MO; contact Lyn Kirschner, Conservation Technology Information Center, 1220 Potter Drive, #170, West Lafayette, IN 47906; (317)494-9555.

March 8, *Nutrient Management Workshop* will be held at Oakland Community Center, Oakland, IA; contact Marco Buske, ISU Extension Crops Specialist, (712)323-2300.

March 10, *Organic Farm Fresh Table Top Exhibition* will be held in Anaheim, CA; contact Pam Breen, Natural Products Expo, (303)939-8440.

March 10-11, *Public Voice's 1994 National Food Policy Conference* will be held in Washington, DC; contact Public Voice, 1001 Connecticut Ave., NW, #522, Washington, DC 20036; (202)659-5930.

March 12-13, *Cultivate Community*, the annual conference of Northeast Organic Farmers Association of New York, will be held at Tompkins/Cortland Community College, Dryden, N.Y.; contact NOFA-NY, P.O. Box 21, South Butler, N.Y. 13154; (315)365-2299.

Creating a farmer sustainability index: A Malaysian case study

Donald C. Taylor, Zainal Abidin Mohamed, Mad Nasir Shamsudin, Mohd Ghazali Mohayidin, and Eddie F.C. Chiew

Abstract. *In on-farm studies of sustainable agriculture, farmers often have been classified as sustainable according to their organizational affiliation; self-identification; or use or non-use of a particular production practice or input, usually synthetic chemicals. Because this is a great oversimplification, researchers recently have been incorporating several dimensions of sustainability into a composite measure. Typically this is a relative measure of sustainability, with scores assigned by comparing individual farmers' practices to those used by all farmers. In contrast, in the farmer sustainability index (FSI) presented here, practices are scored according to their inherent sustainability. We report on the development of an FSI in a case study involving 33 production practices used by 85 cabbage farmers in Malaysia. We describe its underlying principles, the procedure and rationale for scoring each sustainability item, and the result of combining the constituent items into a composite index.*

Key words: integrated pest management, Malaysia, cabbage, diamondback moth, soil fertility

Introduction

Sustainable development is a broad, multifaceted concept. In general, however, sustainable development concerns philosophies and courses of action to help insure a nation's or region's long-term ecological/environmental, social/institutional and economic "staying power." Applied to agriculture, it involves substituting resources produced on-farm for purchased synthetic fertilizers and agricultural chemicals (insecticides, fungicides, and herbicides), and other mechanisms to achieve effective and efficient short- and long-term use of natural resources and people.

Examples of on-farm resources are: 1) integrated pest management for controlling insects; 2) crop rotations, intercropping, and relay cropping to enhance soil fertility, control weeds, and maximize use of space and time; 3) livestock wastes, crop residues, and green manures to enhance soil fertility; 4) nitrogen collected from the air and made available to crops through nitrogen-fixing legumes; 5) minerals released from soil reserves and recycled; 6) water available to crops from enhanced soil moisture retention; 7) varieties selected for resistance or tolerance of insects and diseases; 8) bunds and terraces to control soil erosion; 9) modified planting dates and other cultural practices; and 10) management and labor provided by the farm family.

One way that farmers might be considered "sustainable" is if they deliberately substitute these resources for at least some purchased synthetic fertilizers and agricultural chemicals. Those who substitute natural resources for all synthetic chemicals are commonly termed "organic." Those who use "typical" amounts of synthetic chemicals, on the other hand, are considered "mainstream."

Because sustainability involves many different dimensions—including several that go beyond the use or non-use of synthetic chemicals—the distribution of farmers producing a particular commodity is not simply bimodal, with one cluster of farmers "organic" and the other "mainstream." Rather, the distribution involves a continuum, with farmers' production practices ranging collectively from apparently "very sustainable" to apparently "very unsustainable." The modifier "apparently" is used in this sentence because no one can know with confidence which production practices adopted today will be sustainable over the long-run.

A major concern of some producers and policymakers is that farmers who follow "sustainable" practices may have lower yields and profits than those who follow "mainstream" practices. Policymakers also are interested in knowing which factors influence producers to adopt sustainable practices, so they can promote wider adoption of the practices more effectively. A farmer sustainability index (FSI) is a tool that can help in analyzing these issues quantitatively.

The FSI described here reflects the degree to which individual farmers may be considered "sustainable," based on their use of 33 practices for producing cabbage (*Brassica oleracea capitata*) in Malaysia. (This is "American-type" cabbage, but following local usage, we will call it "English" when necessary to differentiate it from "Chinese" cabbage [*B. chinensis pekinensis*], which is commonly grown in Malaysia and elsewhere in Asia.)

We first discuss recent efforts by other researchers to measure sustainability. We

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then describe the study area where the FSI was developed, its underlying principles and the procedures we used, the rationale for scoring each constituent sustainability item, and the result of combining the constituents into a composite index.

Recent Agricultural Sustainability Studies

In on-farm field surveys on agricultural sustainability, farmers usually are classified as "sustainable" according to their organizational affiliation, self-identification, or a key practice, such as use or non-use of synthetic agricultural chemicals (Taylor, 1990). Comparisons are commonly made between "sustainable" and "conventional" farmers, with occasional attention to an intermediate "transitional" or "mixed" category.

In four studies currently being sponsored by the Northwest Area Foundation (NWAF), in contrast, the practices followed by different farmers are not automatically considered as either "sustainable" or "conventional," but rather as falling on a continuum. In each study, "degree of sustainability" is determined empirically, that is, it is based on actual practices reported by farmers rather than on an *a priori* classification, on whether farmers identify themselves as sustainable, or just on whether they use synthetic chemicals.

The main features of the analysis of sustainability in these studies may be summarized as follows:

1. Menanteau-Horta et al. (1991) studied Minnesota farmers to determine the sustainability of their farm practices with attention to chemical applications, soil conservation, nutrient management, crop/livestock diversity, and energy consumption.
2. Bultena (Iowa State University, personal communication, 1992) developed a sustainability index for surveyed farmers in Iowa based on 11 practices involving production inputs, enterprise diversity, energy use, and personal orientations.
3. Jamtgaard (1992) reported on sustainability indexes developed for three types of farmers and ranchers in Montana. The indexes reflected the cumulative scores for production practices involving chemical fertilizers, pesticides, crop rotations, weed control, manure applications, and crop/animal integration.
4. Cordray and Goetz (undated) developed three scales of sustainability for producers of high-value horticultural specialty crops in western Oregon and Washington. The scales involved the following practices: crop rotations; nitrogen source; control of insects, diseases and weeds; soil erosion control; organic mulches; and manure applications.

As will be seen later, our FSI differs from the work just described in three ways:

- Farmers' attitudes are not included.
- Sustainability scores are established *ex ante* rather than *ex post*.
- Varying weights are assigned to different components.

Study Area and Farmer Sample

Physical conditions

Our FSI was developed in a study of farmers in the Cameron Highlands, Malaysia's oldest and most important area for vegetable production. The highlands consist of a low mountain range with diversely configured valleys of varying width and steepness. Rainfall is highly variable over the year, ranging from 6 to 50 cm/month (GOM-ADB, 1988, p. ES-2) and averaging about 265 cm/yr (Chiew, 1976, p. 43). The soils are derived from disintegration of granite and are acidic and dark-colored, ranging in texture from gravel to rich sandy loam (Lim, 1970). Cameron Highlands has three elevation zones, with the Central zone the highest (1,400-1,500 m above mean sea level) and the North and South zones lying 350-450 m lower (Lim, 1970). The high elevation gives the whole area a warm, temperate climate, but temperatures are higher in the North and South than in the Central Zone. As a result, crops generally are more diverse and pest populations are greater at the lower elevations.

About 1,125 ha of cropland is reported under vegetable production in Cameron Highlands (GOM-ADB, 1988, pp. 3-4). The three vegetable crops grown most extensively are English cabbage, tomatoes (*Lycopersicon esculentum*), and Chinese cabbage (Chiew, 1976, p. 45; Nordin, 1981, p. 124; CHVFA, 1992). In the period November 1991 to January 1992, about 1.3 times as much land was in English cabbage as in tomatoes and 2.25 times as much as in Chinese cabbage (CHVFA, 1992).

Farm characteristics

We obtained data on 44 production practices of cabbage farmers in Cameron Highlands, covering control of insects, diseases, and weeds; erosion control; and maintenance and enhancement of soil fertility. This information was obtained through personal interviews in February 1992 of a purposively selected sample of 85 farmers representing Cameron Highlands' three zones. The farmers were selected roughly in proportion to the area in cabbage production in the respective zones. Their average age was 41. The dominant land tenure is Temporary Occupational License, in which farmers lease cropland from the government year-by-year.

Farms range in size from 0.12 ha to 3.65 ha (average of 0.85 ha). Cabbage is raised in rotation with other crops on 64% of the farms (96% in the North, 85% in the South, and 37% in the Central Zone). Twenty-five percent of the respondents interplant other crops with cabbage.

Integrated pest management

In developing the FSI, we gave particular attention to insect control because of the Malaysian government's efforts to develop and introduce integrated pest management (IPM). The efforts began in the 1960s, and have been intensified in each succeeding decade. The primary focus of IPM on vegetables has been the diamondback moth (DBM) (*Plutella xylostella* [L.]) in the upper portions (1,400-1,500 m elevation) of Cameron Highlands. DBM is the most important insect pest on brassicas; the most important brassica in Malaysia is cabbage (Sivapragasam et al., 1985; Loke et al., 1990; Hamzah Chin et al., 1991).

Historically, the primary means of controlling DBM was synthetic inorganic insecticides. Particularly because of increased resistance of DBM to various chemical insecticides (Henderson, 1957;

Lim, 1974; Sudderuddin and Kok, 1978; Ooi, 1979), farmers began to search for alternative insecticides to control DBM and markedly increased application levels. As many as 40 different chemicals have been used to control DBM (Lim, 1982). Reported side effects of increased insecticide use are poisoning of farmers (Lim, 1970, p. 32; Balasubramaniam, 1974), insecticidal residues in marketed brassicas (Lee and Ong, 1983), hazards to beneficial organisms (Lim, 1982), and environmental pollution (Lim et al., 1988).

In the early 1970s, a parasitoid of DBM (*Apanteles plutellae* [Kurdj]) was discovered in Cameron Highlands. Two additional imported DBM parasitoid species (*Diadegma eucerophaga* [Horst] and *Thyraella collaris* [Grav]) have since proved useful.

The IPM package for DBM control on cabbage involves a procedure for farmers to decide whether to spray for DBM and to know the type of insecticide they should use if they must spray. Such decisions are based on economic threshold levels of DBM and on levels of parasitization. The objectives of the IPM program are to build up and enhance the action of biological control agents, to get farmers to use pesticides judiciously when pesticides must be applied, and to encourage adoption of other suitable agricultural practices.

This approach for implementing IPM in farmers' fields has been modified and improved from time to time. Figure 1 shows the IPM package for DBM control on cabbage that has been used in Malaysia since 1987 (Loke et al., 1990, p. 24). It includes the following strategies:

- Not spraying for low levels of DBM infestation or for moderate infestation when there is a high rate of parasitization;
- Using B.t. (*Bacillus thuringiensis*), a bacterial insecticide, for moderate

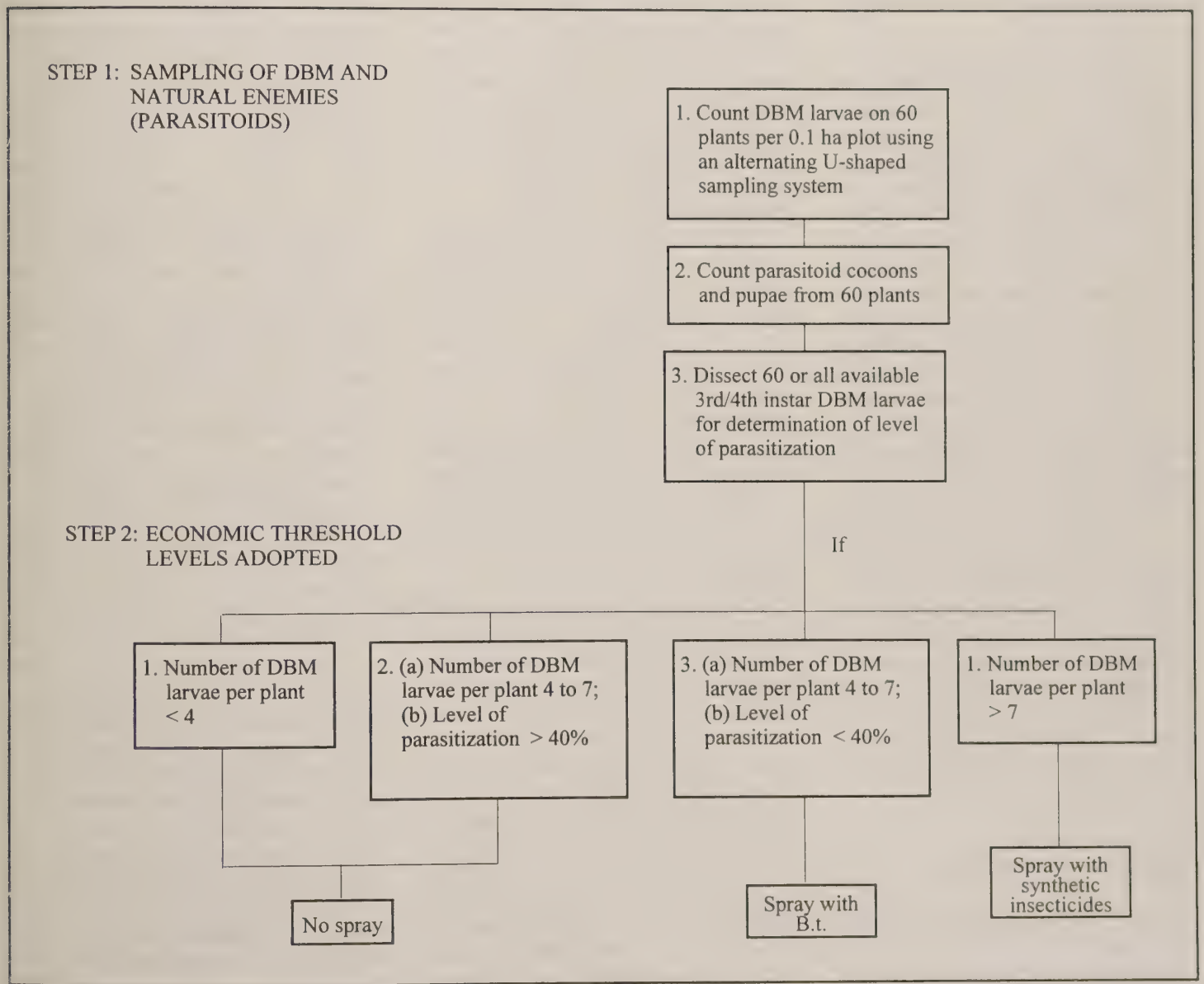

Figure 1. Current IPM Package for DBM Control in Malaysia.

levels of DBM infestation when parasitization is only moderate;

- Using synthetic insecticides for high levels of DBM infestation.

Principles Underlying the FSI

In this section, we discuss the principles involved in developing a single composite index number (the FSI) to reflect the sustainability of farmers' production practices. Differences between our approach and that taken in each of the four NWAF efforts described earlier are emphasized.

Multidimensional conceptualization of sustainability

As in the NWAF studies, our work gives attention to several interrelated dimensions of sustainability, such as agricultural chemical use, soil fertility management, and soil erosion and conservation. However, unlike Bultena (personal communication, 1992), we have not included "personal orientations" involving farmer attitudes. Rather, we limited our index to farmers' practices, and dealt with attitudes only in a later analysis of factors influencing farmers to adopt sustainable practices. Second, unlike Menanteau-Horta et al. (1991) and Cordray and Goetz (undated), who used factor analysis to construct their sustainability indexes, we simply added the various components of the FSI, and reserved factor analysis for a later analysis of how socioeconomic characteristics and knowledge-perception-attitude-belief variables influence adoption of sustainable practices (Mohamed et al., in press).

The FSI included components involving farmers' recent changes in practices, not just their current practices. Thus a farmer whose practices have been moving in the direction of greater sustainability has a higher FSI than one who currently uses the same practices, but is not changing.

Ex post versus ex ante assessment of sustainability

In the NWAF studies, each farmer's sustainability rating for a particular farming practice was scored relative to all farmers' scores for that practice. For example, after the data were collected, Bultena (personal communication, 1992) arrayed the responses to each practice in order, and assigned a rating of "high" to the top quintile, "low" to the lowest quintile, etc.

In contrast, we based our scores on an *ex ante* assessment of the inherent sustainability of each practice. Obtaining a consensus on the sustainability of various practices required much interaction among members of our research team, which consisted primarily of social scientists, and between the team and colleagues from various natural science disciplines.

Different weights assigned to different components

In three of the NWAF studies, the same possible scores (e.g., 1, 2, 3 ...) were assigned to all practices. The fourth (Jamtgaard, 1992, p. 8) used different scales for the various practices, but standardized the responses to individual questions to a mean of 0 and a standard deviation of 1. Therefore, equal weights were assigned to each practice in that study's index also.

Consistent with the decision to score practices according to their inherent sustainability, we assigned different weights to practices according to how strongly each practice is believed to influence sustainability. For example, since regularly following a legume-based rotation can be considered to contribute more to sustainability than regularly intercropping, it was assigned a higher score. Relative importance was reflected in the range of possible scores for each practice and for the practices that collectively constitute each type-of-practice cluster.

We assigned weights iteratively. Scores were first assigned to practices one-by-one, taking account of the implications of each for productivity and profitability, the environment, and human health. We then altered the scores within a cluster of related practices according to how much we judged an individual practice to contribute to sustainability. If the resulting range of scores for the entire cluster was judged inconsistent with the cluster's overall importance, we adjusted the scales for individual practices in that cluster. The process was repeated until we were satisfied with the relative weights both among groups of practices and among individual practices within each group.

Scoring Specific Production Practices

Insect control

With insect control, as with all other practices involved in the FSI, we assigned positive values to practices we believed to contribute to sustainability, such as use of bacterial insecticides, and negative values to practices that detract from sustainability, such as mixing insecticides or fungicides before application. Values of 0 were assigned to neutral practices, such as an intermediate number of sprays to control insects.

Because DBM is a pervasive potential problem for cabbage farmers in Cameron Highlands during the dry season, we scored "calendar spraying" (spraying at regular intervals or prophylactically) during the dry season as neutral for sustainability. Choosing not to spray by the calendar was considered a deliberate action conducive to sustainability, and therefore it was assigned a score of +1 (Table 1).

Three types of field monitoring by farmers were considered consistent with the spirit of IPM control: observing adult plutella moths in the field; observing DBM damage on cabbage plants; and counting DBM larvae on cabbage plants. Since the last of these is part of the formal recommended IPM package and involves farmers making decisions to spray well ahead of damage, it was scored +2. The other monitoring practices were scored +1. For the farmers not to mix "cocktails" of several insecticides or fungicides before application was also considered to be consistent with the spirit of IPM.

A maximum score of +4 was assigned to spraying 1 to 3 times per season and a neutral score (0) to 7-9 sprays per season. This decision was based on results from the Malaysian Agricultural and Research Development Institute's (MARDI) field testing of IPM for DBM in Cameron Highlands, in which a maximum of 3 sprays was required with the IPM package and 7-9 sprayings with prophylactic control (Loke et al., 1990, p. 1). Farmers who do not spray scored lower than those who spray 1 to 3 times, on the assumption that they may have to spray more in later seasons to over-

Table 1. Production practices included in the unadjusted Farmer Sustainability Index (FSI).

Type of production practice	Index score
Insect control (maximum range of scores = 43.5)	
IPM practices	
Basis for deciding to spray for DBM:	
"Calendar spray" in dry season	Yes = 0; No = +1
When adult plutella moths are seen	Yes = +1; No = 0
When DBM damage is seen on plants	Yes = +1; No = 0
Count DBM larvae	Yes = +2; No = 0
Use bacterial insecticide	Yes = +3; No = 0
Mix pesticide "cocktails"	Quite often = -2; Sometimes = +1; No = 0
Number of sprayings for the most important insect during each of the wet and dry season	0 sprays = +2; 1-3 sprays = +4; 4-6 sprays = +2; 7-9 sprays = 0; 10-12 sprays = -2; 13-15 sprays = -4; 16-18 sprays = -6; >18 sprays = -8
Changes over last 5 years in application of insecticides	More now = -4; No change = -2, Less now = +2
Use of non-chemical means for insect control:	
Follow crop rotations	Yes = +0.5; No = 0
Select insect tolerant varieties	Yes = +0.5; No = 0
Adjust crop planting dates	Yes = +0.5; No = 0
Use lime	Yes = +0.5; No = 0
Avoid overhead sprinklers	Yes = +0.5; No = 0
Disease control (maximum range of scores = 8.5)	
Number of sprayings for the most important disease during each of the wet and dry seasons	0 sprays = +1; 1-3 sprays = +2; 4-6 sprays = +1; 7-9 sprays = 0; >9 sprays = -1
Use of non-chemical means for disease control:	
Follow crop rotations	Yes = +0.5; No = 0
Select disease tolerant varieties	Yes = +0.5; No = 0
Adjust crop planting dates	Yes = +0.5; No = 0
Use lime	Yes = +0.5; No = 0
Avoid overhead sprinklers	Yes = +0.5; No = 0

(continued)

Table 1. Production practices included in the unadjusted Farmer Sustainability Index (FSI). (continued)

Type of production practice	Index score
Weed control (maximum range of scores = 6)	
Number of sprayings for the most important weed during each of the wet and dry seasons	0 or 1 spray = +1; 2 sprays = 0; 3-6 sprays = -1
Use of non-chemical means for weed control:	
Use crop rotations	Yes = +1; No = 0
Adjust crop planting dates	Yes = +1; No = 0
Soil fertility maintenance and enhancement (maximum range of scores = 18)	
Percent of total applied nitrogen (N) from organic sources	0% = -1; 1-20% = 0; 21-40% = +1; 41-60% = +2; 61-80% = +3; 81-99% = +4; 100% = +3
Number of applications of inorganic fertilizer	0 or 1 application = 0; 2 applications = +1; 3 applications = +2
Changes over last 5 years in application of:	
Inorganic fertilizers	More now = -2; No change = 0; Less now = +2
Livestock dung	More now = +1; No change = 0; Less now = -1
Other organic fertilizers	More now = +1; No change = 0; Less now = -1
Other means to enhance soil fertility and health:	
Follow crop rotations with legumes	Yes = +1; No = 0
Use slake lime	Yes = +1; No = 0
Use paddy husk carbon	Yes = +1; No = 0
Soil erosion control and multi-purpose practices (maximum range of scores = 6)	
Efforts taken to control soil erosion	Yes = +2; No = 0
Cabbage grown in a crop rotation[1]	Yes = +3; No = 0
Cabbage intercropped	Yes = +1; No = 0
Maximum range of scores in unadjusted FSI = 82	

[1] These points are in addition to the plus 3 points shown above for crop rotations in maintaining/enhancing soil fertility and in controlling insects, diseases, and weeds.

come a possible pest buildup from not having sprayed the previous season.

In general, a level of agricultural chemical use that was lower, the same, or higher than 5 years earlier was considered more sustainable, neutral, or less sustainable, respectively. However, because considerable emphasis has been placed on IPM to control DBM in Cameron Highlands, we decided to give more weight to changes in insecticide use than either fungicide or herbicide use. Similarly, we assigned a negative rather than neutral score to farmers who used the same amount of insecticides as 5 years earlier. The fact that insecticides are more toxic in soil and water than fungicides and herbicides was another rationale for weighting changes in insecticide use more heavily than changes in fungicide or herbicide use. Farmers who followed any of five other non-chemical means for controlling insects were assigned small positive scores.

Disease and weed control

The primary issues with disease and weed control are frequency of spraying, amounts of active ingredients in spray applications (not covered, however, in the index presented here), and the types and extent of non-chemical controls. During the wet season, 51% of responding farmers reported black rot (caused by *Xanthomonas campestris*) as the disease requiring the most effort to control, followed by soft rot (caused by *Erwinia* spp.) (29%) and club root (caused by *Plasmodiophora brassicae*) (13%). In the dry season, the order was club root (36%), black rot (33%), and soft rot (25%).

During the wet season, the weed reported as requiring the most effort to control was "chicken dung" weed (scientific name not available), reported by 39% of responding farmers. This was followed by "rumput" (scientific name n/a) (28%) and "bayam" (*Amaranthus* spp.) (13%). During the dry season, the relative importance of different weed species was similar.

Scores for the number of sprayings and for non-chemical disease and weed controls are shown in Table 1. The same rationale was applied to these scores as for insect control. However, since diseases and weeds have weaker implications for sustainability than do insects, the magnitudes of these scores are lower.

Soil fertility maintenance and enhancement

The primary issues with soil fertility maintenance and enhancement are the overall amount of purchased fertilizer used, the ratio of inorganic to organic fertilizer applied, whether fertilizer is applied just once or twice during the growing season or in several split applications, and the types and extent of non-chemical practices.

The average elemental nitrogen (N), phosphorus (P), and potassium (K) applications per season on cabbage are 395, 250, and 279 kg/ha, respectively, for a total N-P-K application of 924 kg/ha. This application rate is 50% above MARDI's recommended rate for cabbage in lowlands (Vimala and Chan, 1990, p. 39), but 11% less than that reported by Lim (1970, pp. 146-147) and 28% less than that reported by Nordin (1981, pp. 129-131) in earlier surveys of cabbage in Cameron Highlands. Of the total N-P-K applied, 66% is from organic sources. The primary organic fertilizer is chicken dung. However, farmers also use a variety of recently developed manufactured organic fertilizers made from natural rubber serum and byproducts from production of sodium glutamate (Taylor et al., 1993, pp. 2-3, 81).

Taking account of short- and long-term productivity, profitability, and environmental implications, we decided to use the fraction of total applied N from organic sources as a main criterion for the sustainability of a farmer's fertilizer practices. Analogous alternatives considered were the fractions of total P and K from organic sources and the absolute amounts of N, P, and K applied to farmers' fields. However, we rejected these because of inadequate research findings to support establishment of threshold levels for each of these dimensions of fertilizer use.

In general, the higher the fraction of organic N, the more conducive we considered the farmer's fertilization practices for maintaining and enhancing the health of the soil. However, since organic sources may not supply nutrients exactly in proportion to crop and soil nutrient requirements, we gave a slightly lower score to a farmer who relied exclusively on organic sources of N. At the other end of the continuum, points were deducted if a farmer exclusively used inorganic N, a practice that can be detrimental to soil and water quality.

Several small applications of inorganic fertilizer usually are more efficient and less likely to cause leaching of nutrients compared to fewer large applications. Also, late applications can contribute to formation of harder cabbage heads. We therefore decided that the more times farmers applied inorganic fertilizer, the higher their scores.

Scores for changes in the application of various types of fertilizers over the past 5 years and for non-chemical means for enhancing soil fertility are shown in Table 1. The same rationale was applied for assigning scores to these practices as for insect control. However, with livestock dung and other organic fertilizers, in contrast to inorganic fertilizers, we regarded a higher application rate than 5 years ago as a move toward more sustainable practices.

Soil erosion control

Because cabbage is grown in hilly regions, improper management has considerable potential to cause soil erosion. Thus the number and effectiveness of farmers' erosion control measures are strongly related to sustainability.

Erosion control practices were reported by 42% of the farmers interviewed, the two most common and important ones being laying out rows along terraced contours and using sandbags to strengthen field terrace embankments. The scoring for soil erosion control and multiple purpose practices is shown in the final panel of Table 1. (Relatively little attention was given to soil erosion in this study because a study on soil erosion in vegetable farming in Cameron Highlands had been initiated by MARDI and the Asian Vegetable Research and Development Center in Taiwan just before this study began.)

Procedures Used in Combining Component Items into a Composite Index

Missing data

Data on one or more practices were missing for 49 of the 85 farmers in the survey. Any study involving indexes computed from field surveys needs a procedure for handling missing data. Of the four NWAF references cited, only Jamtgaard (1992, p. 8) indicated how this was done, which was to substitute the sample mean for the missing item. This is also recommended in Babbie's (1986, p. 372) textbook treatment of the topic.

In contrast, we imputed values for missing data according to the particular producer's average sustainability for all practices on which we had data. To do this, we first shifted each variable's scale so that the minimum value was 0 and then summed the scores for the practices for which we had data. The ratio of this sum to its maximum value (for those practices for which we had data) represents the average degree of sustainability for that farmer. A score was assigned for a missing practice by multiplying this ratio by the maximum shifted score for that practice.

Item selection

The next three steps in developing the FSI — item selection, examination of bivariate relationships, and index validation — were based directly on Babbie (1986, Chap. 15). They all involve deciding whether to drop some practices from the index.

The questionnaire covered 44 production practices. If all farmers' responses were similar for a particular practice, however, we dropped it from the FSI. Six practices were dropped by this procedure. Composting, mulching, and magnesium lime were each reported by only one farmer, incorporating crop residues or not hand weeding by two, and incorporating green manures by only five.

Eight of the 85 farmers reported having livestock. No farm, however, had a livestock enterprise large enough to interact significantly with its vegetable enterprises. Thus these farmers probably maintained small livestock enterprises to provide homegrown products for their families, rather than to improve the soil or to consume the crop residues and the non-food crops in the rotations. Therefore we dropped having a livestock enterprise from the FSI.

Bivariate relationships

We examined simple bivariate correlations among the remaining 37 candidates for inclusion in the index to determine pairs of variables strongly correlated with each other. In such cases, one or more variables could be dropped, since the remaining variables adequately convey the same information. Three variables — those reflecting changes over the last 5 years in applications of insecticides, fungicides, and herbicides — were strongly correlated among themselves, with all three pairwise correlation coefficients exceeding 0.90. Of the three, we chose to keep the insecticide variable for three reasons: insect control is more critical than either disease or weed control in sustainable cabbage production; sustainable technologies for controlling insects are more highly developed than for either diseases or weeds; and insecticides tend to be more toxic than that either fungicides or herbicides.

In contrast, no variables were only weakly correlated with the others. Therefore, the 35 remaining variables reflected components of sustainability that are partially but not completely independent.

Index validation

We used two approaches to learn how well the composite index provided the intended measure of sustainability. The first, "item analysis," was an internal validation based on correlations between the individual components and the FSI. If a component was only weakly related to the index, it was eliminated. Two practices involving weed control were dropped by this procedure: use of hand tools and machines (each was correlated with the FSI with a correlation coefficient of less than 0.03).

The second approach involved external validation. We invited panels of 4 to 6 natural scientists from various research institutions to react to the scoring system. This was done in two stages: first, with the index as initially proposed by the research team, and again with the index as it emerged from the steps described above. In the first stage, the original scoring system was modified when there was consensus among panel members. Where panel members did not agree among themselves, the team used its best judgment in deciding whether and how to adopt a suggested change. No further changes were made because of the second stage of external validation. Finally, the FSI was multiplied by (100/82) for the convenience of having an index that ranges from 0 to 100 (82 was the maximum value of the unadjusted index).

Farmer Sustainability Index Values

The minimum and maximum unadjusted scores and score ranges for each group of practices are as follows:

- Insect control: -22 to +21.5; range 43.5 points.
- Maintenance and enhancement of soil fertility: -5 to +13; range 18 points.
- Disease control: -2 to +6.5; range 8.5 points.
- Weed control: -2 to +4; range 6 points.
- Soil erosion and multiple-purpose practices: 0 to +6; range 6 points.

Thus, 53% of the maximum range of 82 points (-31 to +51) is related to insect control, 22% to maintenance and enhancement of soil fertility, 11% to disease control, 7% to weed control, and 7% to soil erosion control and other practices.

The 85 farmers' calculated scores varied from 23 to 81 (on a scale of 0 to 100), with an average of 57 (Table 2). The index conforms roughly to a normal distribution, centered around the interval 50 to 60. However, there were more farmers between 60 and 70 than between 40 and 50.

Summary

Agricultural sustainability involves more than simply whether a farmer does or does not use any synthetic fertilizers and agricultural chemicals. There can be a

Table 2. Cabbage final adjusted FSI, Cameron Highlands, 1992.

FSI measure	FSI value
Mean	56.9
Median	57.1
Mode	51.5
Range	23 - 81
Frequency distribution (%)	
0.0 - 40.0	8.2
40.1 - 50.0	11.8
50.1 - 60.0	38.8
60.1 - 70.0	29.4
> 70.0	11.8

situation in which most practices followed by some farmers are viewed as "sustainable," while those followed by others are "unsustainable." The remaining farmers are intermediate on a continuum of sustainability.

Some agricultural policymakers, academics, and practitioners are interested in knowing whether yields and profits are lower in more sustainable systems, and what policies could be developed to encourage more widespread adoption of sustainable practices. In on-farm studies of agricultural sustainability, therefore, it is important to be able to measure "degree of sustainability" satisfactorily. Such an assessment is more meaningful if it is based on the full set of practices the farmer uses, rather than on organizational affiliations, self-identification, or use of a particular practice.

We have explained how we developed a farmer sustainability index that combines 33 different practices used by 85 cabbage producers in Malaysia to control insects, diseases, weeds, and soil erosion, and to maintain and enhance soil fertility. We also have discussed how this index differs from procedures used in four recent studies of "degree of sustainability." We hope this exploratory work adds meaningfully to the growing and increasingly diverse body of literature on sustainable development.

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References

1. Babbie, E. 1986. Indexes, scales, and typologies. In The Practice of Social Research. 4th ed. Wadsworth Pub., Belmont, Georgia.
2. Balasubramaniam, A. 1974. Pesticide pollution. Bull. Public Health Soc. 8:27-32.
3. CHVFA. 1992. Estimated monthly area planted and production, English cabbage, tomatoes, and Chinese cabbage, Cameron Highlands, by zone. Cameron Highlands Vegetable Farmers Assoc., Cameron Highlands, Malaysia.
4. Chiew, E.F.C. 1976. Application of linear programming to farm planning of vegetable farmers in Cameron Highlands. M.Sc. thesis. Dept. of Agricultural Economics, Univ. of Malaya, Kuala Lumpur.
5. Cordray, S.M., and K.W. Goetz. (undated). Issues in sustainable agriculture: A study of horticultural producers in western Oregon and Washington. Final report of the Oregon Tilth and Oregon State Univ. Cooperative Study of Sustainable Agriculture in the Pacific Northwest Maritime Region. Dept. of Sociology, Oregon State Univ., Corvallis.
6. GOM-ADB. 1988. Agricultural marketing project: Case study of vegetable production and marketing in the Cameron Highlands. Prepared by Experience, Inc. (USA) and Perunding Bersatu Sdn. Bhd. (Malaysia). Govt. of Malaysia, Kuala Lumpur, and Asian Development Bank, Manila, Philippines.
7. Hamzah C., Y. Othman, W.H. Loke, and A.R. Syed. 1991. National integrated pest management in Malaysia. Paper presented at Conf. on IPM in the Asia Pacific Region. Organized by CAB International and Asian Development Bank, Kuala Lumpur.
8. Henderson, M. 1957. Insecticidal control of the diamond-back moth (*Plutella maculipennis* Curt.) on cabbage at Cameron Highlands. Malayan Agric. J. 40:275-279.
9. Jamtgaard, K. 1992. Results from the Montana agricultural assessment questionnaire: A survey of sustainable agriculture. Alternative Energy Resources Organization, Helena, Montana.
10. Lee, B.S., and S.H. Ong. 1983. Problems associated with pesticide use in Malaysia. Tropical Agric. Research Series 16:25-35.
11. Lim, K.P. 1970. Economics of vegetable market gardening in Cameron Highlands. M.Sc. thesis. Dept. of Agricultural Economics, Univ. of Malaya, Kuala Lumpur.
12. Lim, G.S. 1974. Integrated pest control in the developing countries of Asia. In D.M. Dworkin (ed). Environment and Development. Scope Miscellaneous Publications, Indianapolis, Indiana. pp. 47-76.
13. Lim, G.S. 1982. The biology and effects of parasites on the diamond-back moth (*Plutella xylostella* [L.]). Ph.D. dissertation. Imperial College at Silwood, Univ. of London, Silwood, Great Britain.
14. Lim, G.S., W.H. Loke, H.H. Chan, and A.R. Syed. 1988. Management of vegetables in Malaysia. Paper presented at the Informal Expert Consultation on IPM in Major Vegetable Crops in Asia. Sponsored by FAO, Regional Office for Asia and the Pacific, Bangkok, Thailand.
15. Loke, W.H., G.S. Lim, A.R. Syed, A.M. Abdul Aziz, M.Y. Rani, M. Md. Jusoh, and U.B. Cheah. 1990. IPM on the diamond-back moth in Malaysia: Development, implementation, and

impact. Paper presented at Second International Workshop on the Management of DBM and Other Cruciferous Pests. Asian Vegetable Research and Development Center, Shanhua, Taiwan.
16. Menanteau-Horta, D., V.M. Juffer, B. Maxwell, and R. Kroese. 1991. Sustainable agriculture in Minnesota. Phase I Report. Center for Rural Social Development, Univ. of Minnesota, St. Paul.
17. Mohamed, Z.A., M.G. Mohayidin, D.C. Taylor, M.N. Shamsudin, and E.F.C. Chiew. (in press). Adoption of sustainable production practices: English cabbage farmers in Malaysia. J. Sustainable Agric.
18. Nordin, M.S. 1981. Vegetable farming in Cameron Highlands. In T.H. Ding, P. Vimala, and Yusoh Salleh (eds). An Agro-Economic Survey of Vegetable Farming in Peninsular Malaysia. Malaysian Agric. Research and Development Inst., Kuala Lumpur. pp. 123-138.
19. Ooi, P.A.C. 1979. An ecological study of the diamond-back moth in Cameron Highlands and its possible biological control with introduced parasites. M.Sc. thesis. Dept. of Zoology, Univ. of Malaya, Kuala Lumpur.
20. Sivapragasam, A., G.S. Lim, and M. Ruwaida. 1985. Experimental trials of an integrated pest management programme for *Plutella xylostella* L. In Proceedings of the Seminar on Integrated Pest Management in Malaysia. Malaysian Plant Protection Soc., Kuala Lumpur.
21. Sudderuddin, K.I., and P.F. Kok. 1978. Insecticide resistance in *Plutella xylostella* collected from the Cameron Highlands. FAO Plant Protection Bull. 26:53-57.
22. Taylor, D.C. 1990. On-farm sustainable agriculture research: Lessons from the past, directions for the future. J. Sustainable Agric. 1(2)43-87.
23. Taylor, D.C., Z.A Mohamed, M.N. Shamsudin, M.G. Mohayidin, and F.C. Chiew. 1993. Sustainability of English cabbage production practices: Cameron Highlands. Staff Pap. 1/93. Faculty of Economics and Management, Malaysian Agric. Univ., Serdang, Malaysia.
24. Vimala, P., and S.K. Chan. 1990. Tanah dan pembajaan (Land and fertilizer). In Panduan Pengeluaran Sayur-Sayuran (Recommended Production Practices for Vegetables). Diversified Crops Research Section, Malaysian Agric. Research and Development Inst., Kuala Lumpur.

RESOURCES

Sustainable Agriculture in Print: Current Books, a bibliography, is available from Alternative Farming Systems Information Center, National Agricultural Library, Room 304, 10301 Baltimore Boulevard, Beltsville, MD 20705-2351; (301)504-5724.

The Humane Consumer and Producer Guide, 368 pages, is available for $15 from the Humane Society of the United States, 2100 L St., NW, Washington, D.C. 20037; (202)452-1100.

High Quality Leaf Compost: A Production Guide is $12 plus $2 shipping from Moody Hill Farms, RR 2 Box 347, Millerton, N.Y. 12546.

Greenbook '93—Report of Energy and Sustainable Agriculture Program Activities, 117 pages, is available from Energy and Sustainable Agriculture Program, Minnesota Department of Agriculture, 90 West Plato Boulevard, St. Paul, MN 55107; (612)296-7673.

The Illinois Sustainable Agriculture Network's 1992 On-Farm Participatory Research Program, 98 pages, is $5 from ISAN, P.O. Box 648, Rochester, IL 62563; (217)498-9705.

On-Farm Composting Handbook is $15 from Northeast Regional Agricultural Engineering Service, 152 Riley-Robb Hall, Ithaca, N.Y. 14853-5701; (607)255-7654.

Stemming the Flow, a study of agrichemical dealers and practices in the Great Lakes Basin, is $32 from Environmental Working Group, 1718 Connecticut Ave., NW, #600, Washington, D.C. 20009; (202)667-6982.

Community Supported Agriculture Database is available, with free access, from Bio-Dynamic Farming and Gardening Association, P.O. Box 550, Kimberton, PA 19442; (215)935-7797.

1993 Washington Tilth Directory, a guide to organic and sustainable growers and resources, is $2 from Washington Tilth, P.O. Box 85056, Seattle, WA 98145; (206)527-9216.

Tradeoffs Between Water Quality and Profitability in Iowa Agriculture is available from Public Policy Center, The University of Iowa, Iowa City, IA 52242.

Our Right to Eat—Safely: Challenging the World Food System, eight pages, is available from Global Exchange, 2017 Mission St., #303, San Francisco, CA 94410; (415)255-7296.

Agronomic, Economic, and Ecological Relationships in Alternative (Organic), Conventional, and Reduced-till Farming Systems is available at no charge from Agricultural Bulletin Room, Lincoln Music Hall, Room 112, South Dakota State University, Brookings, S.D. 57007; (605)688-5628.

Farming and Clean Water, a community action guide, 116 pages, is $15 from The Minnesota Project, 1885 University Ave. W, #315, St. Paul, MN 55104; (612)645-6159.

Agricultural Nonpoint Source Pollution: Toward a Consensus Approach to Its Abatement is available from American Farmland Trust, 1920 N St., NW, #400, Washington, D.C. 20036; (202)659-5170.

Soil and Water Quality: An Agenda for Agriculture, a report by the National Research Council, is available from Carla Carlson, Board on Agriculture, (202)334-2252.

Farm Policies and the Sustainability of Agriculture: Rethinking the Connections, by Neill Schaller, and *Enhancing Agricultural Sustainability Through Changes in Federal Commodity Policy: Marginal Versus Radical Change*, by Thomas L. Dobbs, the Wallace Institute's Policy Studies Program Reports Nos. 1 and 2, are $6 each from the Wallace Institute, 9200 Edmonston Road, #117, Greenbelt, MD 20770; (301)441-8777.

Agronomic and economic potential of sustainable agriculture in South India

Erik van der Werf

Abstract. *The development of sustainable agriculture in India has been limited by the absence of data on the agricultural and economic viability of ecological agriculture and its longterm prospects. This paper describes a two-year study of seven farm pairs, each consisting of one ecological and one comparable conventional reference farm. The ecological farms differed significantly from the conventional farms in the number of crops grown, the dependence of crop activities on external nutrients, and the number of techniques used to maintain soil fertility and create plant diversity. No significant economic differences were found. Gross income, variable costs, gross margin and net cash income per hectare were in the same range for the two groups of farms. The two groups were similar in average yields for major crops, days of labor per hectare, and total returns per day of labor.*

Key words: farming system, sustainability, ecological agriculture, labor, soil fertility, income, India

Introduction

Efforts to promote socially just, economically viable and ecologically sound land use systems in India are beset by the almost complete lack of data on the performance and potential of ecological agriculture, specifically in comparison with conventional practices. One such effort is the Agriculture, Man and Ecology (AME) program in Pondicherry, a program carried out by the ETC Foundation, Leusden, the Netherlands, with financial support from the Netherlands Government. Because the lack of data on ecological agriculture was hampering its ability to affect policy, in 1989 AME began a research project with the following objectives:

- To analyze, qualitatively and quantitatively, the viability of ecological agriculture, both by itself and in comparison with conventional agriculture.
- To examine the long-term prospects for ecological agriculture.

This paper describes two years of field work from this project.

Methods

The study covered seven farm pairs in the Indian states of Karnataka, Tamil Nadu and the Union Territory of Pondicherry. Each pair consisted of an ecological farm and a comparable reference farm practicing conventional agriculture. Taking into account comparative research experiences in the West (Lampkin, 1984, 1986; Lockeretz et al., 1984) and the limited number of established ecological farms in South India, we chose a comparative case study approach (Werf and Jager, 1992). Case studies are particularly useful in identifying problem areas and possible solutions (Lampkin, 1984). These are relevant goals, because despite the early work there by Sir Albert Howard (1943), sustainable agriculture in India is still in an early stage of development, and the key question is "Is it all possible?" (Kirschenmann, 1992). This paper seeks to give a preliminary answer to this question. Maxwell (1984) recommends the case study approach specifically for situations where a range of enterprises is under consideration, not just one crop.

In this research, ecological agriculture was defined as a production system with the following characteristics: no application of any chemical fertilizers, herbicides or insecticides; optimizing the use of local resources; and deliberately applying ecological farming principles, such as stimulation of diversity and complexity within the farm. South Indian farms meeting this definition were identified through a survey among non-governmental organizations active in agricultural development. Within this group of approximately twenty farms, seven were selected according to their representativeness, the farmers' willingness to participate, and the requirement that the farm had been managed ecologically for at least three years.

Each selected ecological farm was paired with a similar conventional reference farm that uses external inputs, specifically fertilizer and pesticides. Suggestions for a conventional reference farm for each ecological farm were obtained from the ecological farmer and agricultural extension workers. Selections were made to get the best match with each ecological farm in soil type, topography, size, cropping pattern, livestock activities, irrigated/rainfed cropping, intensity of farming, distance between house and farm, and the quality of farm management. The comparability of

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the two groups is shown in Table 1. The average distance between two farms within a pair is 0.8 km, with the range from 0 (immediate neighbors) to 3 km. Most ecological farmers practiced ecological agriculture for 7 to 9 years (range 5 to 11).

Climate in the study area ranges from semi-arid for the inland portion, with a normal rainfall of around 600 mm/year, to around 1200 mm/year for the coastal plains. However, there are considerable annual fluctuations. During the first year of this study, rainfall was near normal, but during the second year it was well below normal.

We collected data every two months on all relevant aspects of the crop and livestock enterprises: inputs and outputs (amounts and monetary value), total labor requirements, and total cash flow. The farmers were actively involved in data collection. Results were tabulated for each farm pair and verified and discussed with the participating farmers in individual and group discussions. We presented results in detailed agronomic and economic sectional reports (Sivasubramanian and de Jonge, 1990; Institute for Command Studies and Irrigation Management, 1990, 1991; Pushpalatha, 1992). An overall report has been published for each year (Werf and Jager, 1992; Werf et al., 1992); this paper is largely based on these reports. Although the research is based on the case study approach, in this paper I attempt to analyze several general outcomes of the two farming systems, while taking account of the characteristics of the individual farms.

Table 1. Main farm characteristics of ecological and conventional farms (median, with minimum and maximum values in parentheses).

	Ecological	Conventional
Holding size (ha)	3.7 (1.8 - 12.1)	2.5 (1.6 - 4.0)
Fraction irrigated (%)	71 (0 - 96)	68 (19 - 92)
Fraction of total gross income from crop activities (%)	84 (25 - 98)	90 (77 - 99)
Livestock weight (kg/ha)	475 (260 - 687)	425 (0 - 1166)
Families living on farm (%)	86	29

Table 2. Agronomic characteristics of ecological and conventional farms (median, with minimum and maximum values in parentheses).

	Ecological	Conventional
Number of crops per farm	11 (6 - 14)	8 (3 - 12)
Number of trees/ha	192 (17 - 519)	37 (10 - 83)
Total external nutrients (kg/ha)	77 (23 - 100)	114 (40 - 465)
Fraction of crop nutrients from external sources (%)	37 (17 - 58)	67 (32 - 79)
Number of techniques used to maintain soil fertility	5 (3 - 8)	4 (2 - 6)
Number of techniques used that increase plant diversity	5 (3 - 7)	1 (0 - 3)

Results

Agronomic aspects

Table 2 gives average figures for key agronomic variables for both farming systems. On the ecological farms more species of crops are grown than on the conventional farms (median of 11 versus 8). On the ecological farms, pulses account for 17% of the crops grown, compared with only 8% on the conventional farms (which is also the state average). Most ecological farms grow some fodder crops, such as Napier grass (*Pennisetum purpureum*) and fodder sorghum (*Sorghum vulgare*), mainly along field borders and irrigation ditches, but also in plots. In contrast, none of the conventional farms grow fodder crops. Vegetable production is more important on the conventional farms, particularly for the market. All the ecological farms have more trees per hectare than the conventional farms, with more species grown: median of 21 species (range 4 to 72) against 6 for the conventional farms (range 2 to 11). Trees on the ecological farms, mostly grown in combination with annual crops, produce fruit, fodder, green manure, fixed nitrogen, and fuel and construction wood. They also are used as windbreaks, to improve the microclimate, to provide permanent soil cover and leaf litter, and to recycle nutrients leached to deeper soil layers.

On each ecological farm, external inputs of N, P and K separately are all less than on the conventional counterpart. Dependence on nutrients obtained from outside the farm, calculated as total N, P and K, in kg/ha, is 32% lower on the ecological farms than on the conventional group. The ecological farms depend on external sources for 33% of their N, 40% of their P, and 34% of their K (37% overall). The main external sources of nutrients for ecological farms are farmyard manure, poultry, sheep and goat manure, and silt from irrigation tanks. Small quantities of neem cake and green leaf manure also are used.

In comparison, the conventional group is more dependent on external nutrient sources, with 57%, 69%, and 56% of their supplies of N, P and K, respectively, obtained externally (67% overall). Chemical fertilizers account for 62%, 60%, and 48%, respectively, of the external supplies of these nutrients. The main internal nutrient sources are farmyard manure, symbiotic nitrogen fixation, and to a lesser extent green leaf manures. Total nutrient input per hectare (including nutrients in externally

obtained animal feed) on the ecological farms is 73% that of the conventional farms (see Table 3). This can be explained by their lower use of external nutrients and their more efficient nutrient management practices.

More techniques to maintain soil fertility are used on the ecological farms than on the conventional group (median of 5 versus 4; see Tables 2 and 4). These techniques include composting, (live) mulching, application of night soil and other organic matter, and the use of the effluent from biogas production. Deep-rooting crops are grown by nearly all farmers, but they are slightly more important on the ecological farms, covering 46% of the gross cropped area (in year 2), a quarter of which is under trees. On the conventional farms, in comparison, they cover only 34% of the cropped area, of which only one-ninth is under trees. Farmyard manure is used by all the farmers, but the ecological farmers generally handle manure better. During storage, manure is protected from direct sun and rain, and field application is timed better. On two ecological farms, cattle urine is collected separately for use as a foliar nitrogen spray for rice and for crop protection. The ecological farmers also pay greater attention to the effectiveness of storage and the timing and amounts of field applications. Green leaf manures are mainly used in irrigated rice cultivation. Biofertilizers are used experimentally by some ecological farmers, for example *Azospirillum* for rice and *Rhizobium* for trees. 'Other organic matter' in Table 4 includes silt from irrigation tanks and purchased manures from poultry and pig farms.

Ecological farmers use considerably more techniques for managing plant diversity than do conventional farmers (5 versus 1; see Table 2). Mixed cropping (with the species either completely intermixed or in separate rows) not only is more frequent on the ecological farms but also is practiced in much more complex systems. Whereas conventional farmers mainly have mixtures of two to four crops, many ecological farmers intercrop four to eight crops. One ecological farmer grows the following mixture on one-tenth of a hectare: turmeric (*Curcuma domestica*), onion (*Allium cepa cepa*), chili (*Capsicum frutescens*), castor (*Ricinus communis*), cucumber (*Cucumis sativus*), okra (*Hibiscus sabdariffa*), eggplant (*Solanum melongena*) and soybean (*Glycine max*).

Trees, whether as hedges/shelterbelts, multistory cropping, or other forms of agroforestry, are much more important on the ecological farms. Multistory cropping, selective weeding, cover crops, and on-farm tree nurseries are found only on the ecological farms (see Table 5).

Table 3. Input of major nutrients (kg ha^{-1} yr^{-1}) on ecological and conventional farms (median, with minimum and maximum values in parenthesis; in 1990).

	Ecological	Conventional
N[1]	61 (25 - 88)	84 (58 - 223)
P	8 (3 - 17)	16 (2 - 105)
K	19 (5 - 39)	20 (8 - 145)

[1] Including estimated N-fixation from leguminous crops.

Table 4. Proportion of ecological and conventional farms using specific practices for soil fertility maintenance for two consecutive years (%).

	Ecological	Conventional
Farm yard manure	100	100
Deep-rooting crops	100	86
Night soil	86	29
Green leaf manure	57	43
Green manure (excluding trees)	14	29
Compost (farm or urban origin)	29	0
Other organic matter	29	0
Use of biogas tank effluent	14	0
Mulching (dead or live)	14	0
Use of biofertilizers	0	0

Table 5. Proportion of farms practicing specific techniques for creating plant diversity on ecological and conventional farms for two consecutive years of research (%).

	Ecological	Conventional
Mixed/intercropping	100	57
Hedges/shelterbelts	100	29
Agroforestry/alley cropping	71	14
Cover crops	43	0
On-farm tree nurseries	43	0
Multistory cropping	29	0
Selective weeding	14	0

Economic aspects

The economic results (Table 6) differ greatly among farms within each group and between the two years. Gross income was calculated as the market value of all crop and livestock production, including products sold and consumed at home, using identical prices for the conventional and ecological farms. In four of the seven pairs, the ecological farm had a higher gross income per hectare than the conventional farm. However, this number of ecological farms also had higher variable costs per hectare. (The variable costs include all direct costs that vary with the size of the activity, such as seeds, manure, fertilizers, pesticides, transportation, hired labor, animal traction, fodder, and concentrates.) Operator and family labor is not included here, but was calculated separately as returns per person-day. In calculating costs for crop or livestock production, materials produced on-farm were charged at market rates. Thus straw for fodder is a return to the crops and a cost to the livestock enterprises, with the reverse true for manure.

In four pairs, gross margin per hectare (gross income, including the value of products consumed by the household, minus variable costs) was higher on the conventional farms. Table 6 lists the median, minimum and maximum values for these variables. For crops, gross margins tended to be higher on the conventional farms, but for livestock activities they were similar. Net cash income per hectare — equal to cash income from sales minus the variable and fixed costs paid in cash — was higher on the ecological farm in five of the seven pairs.

Total variable costs for crops per hectare are in the same range for the ecological and conventional farms (Table 7). Because of cultivation of mulberry leaves (*Morus alba*) for silkworm production on one ecological farm, the highest variable cost is nearly Rs 24,000/ha. Since both groups' cropping intensity is about 1.6 crops per unit area per year, costs per cultivated crop also are comparable.

The structure of variable costs differs for the two groups. Seed costs are greater for the conventional farms, but the cost of manure, including internal deliveries, is greater in the ecological group. However, the conventional group spends an average of 13% more on fertilizer. Of variable costs for crops, 22% is for soil fertility on the ecological farms compared with 29% for the conventional farms. Pesticide use on the conventional group is low (2-3 kg/ha), accounting for 5% of variable costs for crops, but varies strongly among crops and farms.

Livestock activities generally have considerably lower gross margins than crop activities (see Figure 1). Expenditures on livestock are higher among ecological farmers. However, as discussed later, on conventional farms livestock are kept mainly for traction (predominantly bullocks and buffaloes), whereas on ecological farms, the manure, milk, eggs and meat they produce also are very important.

Five ecological and four conventional farms realize a return per day of operator and family labor equal to or higher than the going rate for unskilled male agricultural laborers (Rs 15 per person-day). For both groups, median returns are approximately twice this rate (30 and 27 Rs/person-day for the ecological and conventional farms, respectively).

The two systems do not differ much in the number of person-days/ha. In both, about half the labor is supplied by women.

Analysis of individual crops

In all but one pair, yield of irrigated rice (*Oryza sativa*) per hectare was higher with ecological practices than on the conventional farms (range -6% to +119%); the

Table 6. Key economic variables on ecological and conventional farms during two years of research (median, with minimum and maximum values in parentheses; in 1990, 1 US$ = 16.5 Rs).

	Ecological	Conventional
Gross income (1000 Rs/ha)	9.1 (4.6 - 53.4)	13.8 (3.6 - 30.3)
Variable costs (1000 Rs/ha)	4.0 (3.5 - 23.8)	5.2 (2.8 - 11.8)
Gross margin (1000 Rs/ha)	4.9 (-0.4 - 29.6)	8.2 (0.2 - 22.9)
Returns/person-day (Rs)	30 (17 - 58)	27 (8 - 68)
Net cash income (1000 Rs/ha)	2.9 (-0.4 - 51.8)	2.3 (-1.0 - 31.3)
Person-days/ha	206 (79 - 513)	223 (140 - 435)
Fraction of products sold (%)	44 (32 - 66)	57 (9 - 79)
Assets (1000 Rs/ha)	79.8 (24.4 - 136.2)	84.1 (45.8 - 138.3)

Table 7. Distribution of costs for crop activities (%) on ecological and conventional farms during two years of research.

	Ecological	Conventional
Seeds	15	19
Manure	22	16
Fertilizer	—	13
Agrichemicals	—	5
Paid labor[1]	45	43
Others	18	4
TOTAL	100	100

[1] External labor only (does not include family labor).

median paddy yield on the ecological farms was 54% greater than that of the conventional farms (Table 8). However, yields differed considerably between years and from pair to pair. Nutrient inputs were comparable between the two groups. The nutrient balance at the field border (calculated as inputs of mineral fertilizer, organic manure and biological N fixation by green manures grown immediately before the rice, minus nutrients in the harvested portion and in the residues removed) was lower on the ecological farms. However, losses through volatilization of N and leaching, which are likely to be higher with fertilizer than with organic manures, have not been taken into account in this study. Nor have I included any difference in the efficiency of internal recycling, which is thought to be better on ecological farms. These points will need more attention in the continuation of this study. Until then, it is hard to estimate the importance of the lower nutrient balances in the ecological farms. Most of the farms studied have had ecological practices used on them for seven to nine years; despite the negative nutrient balances, rice yields are still good, often better than on the conventional farms.

Table 9 shows the yields of the five most frequently cultivated crops. Only irrigated production is considered for rice, finger millet (*Eleusine coracana*) and peanut (*Arachis hypogaea*), and only rainfed production of sorghum and sesame (*Sesamum indicum*). Because there were only a few observations for these crops, the figures should be considered as indicative only. Median yields and minimum-maximum ranges do not show major differences between the two farming systems.

Livestock

There is no significant difference between the ecological and conventional farms in total livestock (average livestock weight of 475 kg/ha for the ecological versus 450 kg/ha for the conventional farms). However, livestock play different roles on the two groups. On the ecological farms, 24% of gross income is from livestock, against only 10% on the conventional farms. Variable livestock costs are double on the ecological farms, mainly because of purchased concentrate and fodder. On the

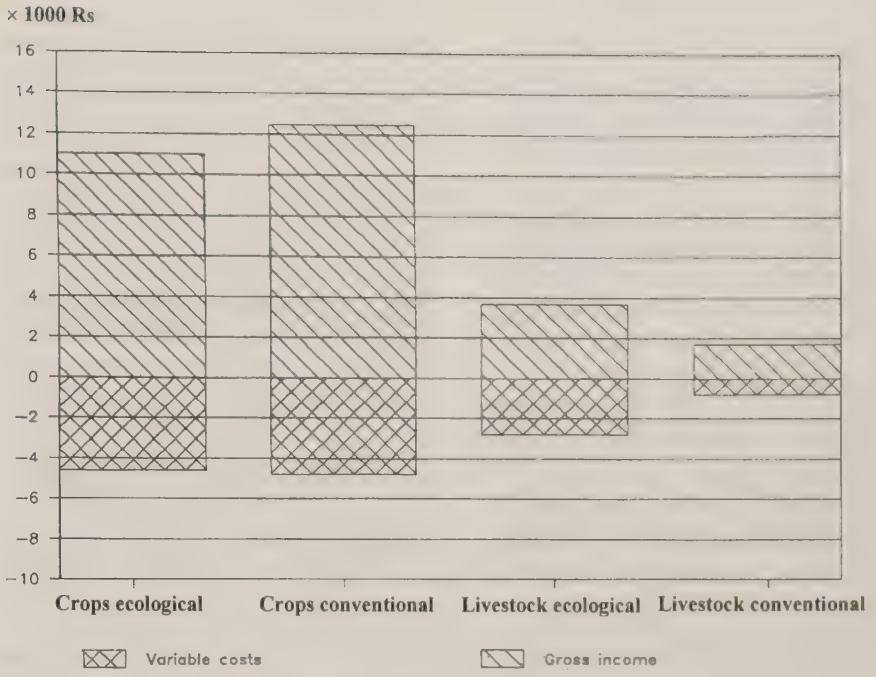

Figure 1. Average gross income and variable costs for crop and livestock activities on ecological and conventional farms.

Table 8. Rice yield, nutrient inputs and nutrient balance at field border for N, P and K (median, with minimum and maximum values in parentheses).

	Ecological	Conventional
Rice yield (kg/ha)	3078 (2000 - 9700)	1994 (912 - 7173)
N input[1]	103 (28 - 241)	113 (37 - 181)
P input	13 (7 - 76)	21 (7 - 49)
K input	65 (10 - 96)	57 (15 - 106)
N balance[1]	-3 (-177 - 187)	38 (-134 - 154)
P balance	-3 (-25 - 11)	7 (-19 - 17)
K balance	-20 (-145 - 17)	-3 (-127 - 70)

[1] Including estimated N-fixation from leguminous crops.

Table 9. Yields (kg/ha) of major crops on ecological and conventional farms (median, with minimum and maximum values in parentheses), and Karnataka state averages, 1990-1991.

	Ecological	Conventional	Karnataka
Rice[1]	3078 (2000 - 9700)	1994 (912 - 7173)	3165
Sorghum[2]	982 (274 - 1207)	510 (375 - 1200)	725[3]
Finger millet[1]	2000 (1700 - 3703)	2133 (2000 - 3320)	1200[3]
Peanut[1]	955 (389 - 2000)	854 (743 - 964)	822[3]
Sesame[2]	365 (165 - 450)	320 (264 - 375)	338

[1] Irrigated only.
[2] Rainfed only.
[3] Average for all land (irrigated and rainfed).

conventional farms, livestock are kept for two main reasons: for traction, which makes them a component of crop production, and for milk (dairy cattle). On the ecological farms, in contrast, livestock and crop production are considered equally important components of the farming system, and they are much more closely integrated. Beside draft and dairy cattle, the ecological farms have goats, sheep, poultry and to a lesser extent ducks and rabbits.

Beside producing meat, sheep and goats are important for manure production. During the day the animals graze outside the farm, where they receive most of their fodder requirements. At night they are stabled on the farm, both to protect them and to collect the manure. In general, the ecological farmers pay more attention to collection, processing, storage and spreading of manure than their conventional colleagues. Perhaps they consider the manure a compensation for the lower rate of return on livestock compared with crops (Figure 1).

Discussion and Conclusions

The case study approach and the limited number of cases studied mean that we must be very careful about drawing conclusions. In each group, the farms range from fully market-oriented to near-subsistence, from small to large, and from fully irrigated to rainfed only. Despite this variability, the groups as a whole differ considerably in several farming practices.

Agronomic aspects

Besides differing in their use of chemical fertilizers and pesticides, the two groups diverge in five other agronomic aspects.

Number of crops. The ecological farmers cultivate more crops mainly to ensure better soil cover, increase nitrogen fixation, and create diversity to enhance stability. However, we cannot say yet whether the expectation of greater stability is fulfilled.

External nutrients. The ecological farmers are less dependent than the conventional farmers on external sources of nutrients for their crops. Their lower use of external inputs and non-use of chemical fertilizers and pesticides do not prevent them from obtaining yields comparable to the conventional group's. This suggests that ecological farms are more efficient in their internal recycling. The mechanisms responsible for this were not examined in detail in this study, but some hypotheses may be advanced. The first hypothesis is that leaching of nutrients from the topsoil is lower on the ecological farms because of the greater importance of deep-rooting species (both annuals and perennials). The second is that recycling through livestock is better for the ecological group because these farmers pay more attention to the management of manure. Also, losses through leaching and volatilization/denitrification generally are lower for organic manures than for inorganic fertilizers. Furthermore, the more diverse crop mixtures grown on the ecological farms also might contribute to more efficient nutrient recycling. Finally, ecological farmers raise more nitrogen-fixing crops than their conventional counterparts.

Soil fertility. Ecological farmers use more techniques to maintain soil fertility, and do so on a larger scale and more efficiently.

Plant diversity. Ecological farmers' greater use of techniques involving plant diversity result in more intensive land use and better soil cover throughout the year. Both kinds of farmers practice multiple or relay cropping, and the two groups are similar in cropping intensity, but the ecological farms have more mixed and intercropped land, with more species in the mix.

Yields. Yields vary considerably within the groups and between years, but do not differ significantly between the groups. In one year the ecological group may achieve the higher yield for a specific crop, the next year the conventional group. However, rice yields were higher on ecological than on conventional farms in both years.

Two years of an agricultural survey is too short to reach firm conclusions. However, the agronomic evidence collected so far suggests that the ecological farms are as productive and profitable as the conventional farms, with the added advantage of lower dependence on external nutrients and greater diversity in both crops and cropping practices.

Economic aspects

Despite the differences in agronomic approaches noted above, the two groups show no significant overall differences for the major indicators of economic performance, although there is great variation within each group. However, there is an important difference in the enterprise mix of the two groups, with livestock more important on the ecological farms. This lowers their gross margin because the average margin for livestock is considerably lower than for crops. Returns to labor are comparable between the ecological and conventional farms. Despite the common assumption that ecological agriculture requires more labor than conventional agriculture, this was not found in this study.

Extrapolations

These results are among the limited available data comparing ecological and conventional agriculture at the farm level in a developing country. Although two years is too little to draw firm conclusions, some extrapolations are possible to the national level. The data suggest that ecological farms can perform just as well as conventional farms despite using no chemical inputs. They can produce similar levels of outputs, supplying the farmer with similar returns to labor. However, their output is different. Ecological farms grow proportionally more pulses, whereas conventional farms grow more oil crops and vegetables.

Extrapolated nationally, this means that ecological agriculture does not threaten food security in the short-run. Nor does it do so in the long-run, because ecological practices may be expected to reduce soil erosion and the depletion of soil fertility. Also, the lower dependence on external inputs is likely to have a positive influence on foreign exchange reserves. Practices from ecological farming can be used to increase the efficiency of conventional farming. This is particularly true for internal recycling of nutrients, improved manure management, the greater use of nitrogen-fixing species, and inclusion of trees in the farming system.

References

1. Howard, Albert. 1943. An Agricultural Testament. Oxford Univ. Press, New York and London.
2. Institute for Command Studies and Irrigation Management. 1990. A Report on Ecological Farming in South-India, An Economic Analysis. Bangalore, India.
3. Institute for Command Studies and Irrigation Management. 1991. A Report on Ecological Farming in South-India, An Economic Analysis. Bangalore, India.
4. Kirschenmann, F. 1992. Naar een alternatieve mythologie: Vijf-stappenplan. Vruchtbare Aarde, No. 5, pp. 4-9.
5. Lampkin, N. 1984. Problems of comparison in biological farming. New Farmer and Grower, No. 5, pp. 17-20.
6. Lampkin, N. 1986. A research concept for investigating organic farming systems: Case studies. In P. Allen and D. Van Dusen (eds). Global Perspectives in Agroecology and Sustainable Agricultural Systems. Proc. Sixth Scientific Conf. of the International Federation of Organic Agriculture Movements. Agroecology Program, Univ. of California, Santa Cruz. pp. 121-127.
7. Lockeretz, W., G. Shearer, D.H. Kohl, and R.W. Klepper. 1984. Comparison of organic and conventional farming in the corn belt. In D.F. Bezdicek, and J.F. Power (eds). Organic Farming: Current Technology and Its Role in a Sustainable Agriculture. Spec. Pub. 46. Amer. Soc. Agronomy, Crop Sci. Soc. Amer., and Soil Sci. Soc. Amer., Madison, Wisconsin. pp. 37-48.
8. Maxwell, S. 1984. The Role of Case Studies in Farming Systems Research. Institute for Development Studies, Sussex, England.
9. Pushpalatha, A. 1992. Ecological Farming in South India, An Agricultural Comparison, 1990-1991. Agriculture, Man and Ecology, Pondicherry, India
10. Sivasubramanian, K., and A. de Jonge. 1990. Sustainability Analysis of Ecological Agriculture in South-India. Agriculture, Man and Ecology, Pondicherry, India.
11. Werf, E. van der, and A. de Jager. 1992. Ecological Agriculture in South-India, An Agro-economic Comparison and Study of Transition. Agricultural Economics Research Institute, The Hague, and ETC-Foundation, Leusden, the Netherlands.
12. Werf, E. van der, G. Keshav Rao, A. Pushpalatha, and Francis Xavier A. 1992. An Agro-economic Comparison of Two Years of Research in Ecological and Conventional Agriculture in South-India. Agriculture, Man and Ecology, Pondicherry, India.

BOOK REVIEWS

Mycorrhizae in Sustainable Agriculture. Edited by G.J. Bethlenfalvay and R.G. Linderman. 1992. American Society of Agronomy, 677 S. Segoe Road, Madison, WI 53711. $18.00, paper. 124 pp.

This book is based on symposium presentations at the 1991 Annual Meeting of the Agronomy Society of America. Its five chapters include discussions of the role of mycorrhizae in crop productivity (G.J. Bethlenfalvay), soil conservation (R.M. Miller and J.D. Jastrow), soil microbial interactions (R.G. Linderman), cultural stresses (N.C. Johnson and F.L. Pfleger), and environmental stresses (D.M. Sylvia and S.E. Williams). The contributors and editors have consolidated substantial evidence documented by comprehensive citations showing that functional arbuscular mycorrhizae (AM) are critical to sustainable agroecosystems, soil productivity, and soil quality. Information in the individual chapters will provide the reader with an accurate overview of the ways in which these fungal-plant symbionts integrate biochemical and physical processes important to sustainable agricultural systems, forming, as the authors describe it, "a fundamental link between the biotic and abiotic portions of the agroecosystem." Within the framework of Hierarchy Theory, the editors note that AM constitute a critical lower-level component (that is, part of the soil microbial processes) of a larger-scale system, a component scarcely considered in most assessments of the efficiency and effectiveness of alternative agricultural practices in agroecosystems. They espouse the view that "VAM fungi are the universal compensators needed to accomplish the mission of sustainable agriculture." Readers will need to evaluate this view with regard to their specific field situations.

The first chapter provides agricultural scientists who are non-specialists in mycorrhizae with a basic overview of AM as microbial colonists of soils and plants, including their diversity and specificity. It sets the stage for subsequent chapters by describing how the fungal partners of the symbiosis are affected by environmental conditions and cultural practices such as drought, salinity, fertilizers, pesticides, crop rotation, fallowing, soil disturbance, and intercropping.

The second chapter, which rates as the outstanding chapter of the book, provides an excellent, succinct and lucid review of the role of AM in soil conservation, especially regarding microaggregate formation and soil stabilization. This subject has scarcely been examined in other recent reviews on mycorrhizae. Miller and Jastrow have made an excellent contribution that thoroughly explains the most relevant facts and issues concerning AM and conservation of soil structure.

In the third chapter, Linderman describes many interactions between AM and other soil microorganisms in the framework of the mycorrhizosphere, that is, the rhizosphere extended to include the mycorrhizae. Although this information is available in other recent reviews, readers who do not have ready access to them will find this chapter, with its list of current references, very useful. In substantiating the role of AM as microbes integral to the rhizosphere, Linderman describes the effects of microbes on AM and the influence of AM on biological nitrogen fixation, biological control of soilborne plant diseases, and various other beneficial soil microbes.

The fourth chapter presents an overview of recent conclusions about the effects of cultural practices on AM with a view toward understanding their basis and possible implications for alternative agricultural

systems. Johnson and Pfleger describe what is known about the effects of cropping sequence, fertilizers, tillage and pesticides on species composition. This chapter supplies detailed explanations of the concepts introduced in the first chapter.

In the fifth chapter, Sylvia and Williams offer extensive documentation of the effects of various soil environmental stresses on the occurrence, distribution, and effectiveness of AM. They describe the adaptability of AM to various soil conditions, including nutrient concentrations, water content, aeration, compaction, pH, osmotic stresses, heavy metals, pathogenic microbes, and organic matter.

There is considerable redundancy among portions of several chapters because the individual papers from the ASA symposium were simply collected, instead of being edited to select and interweave the salient points of each. Nevertheless, this moderately priced book will be a useful addition to the reference collection of agronomy students and other agricultural scientists who need a concise source of basic concepts about AM, particularly in relation to sustainable agriculture, soil quality, and soil conservation. The reader will gain a good insight into the difficulties confronted by researchers who work on this phenomenon, and into the complexity of the interactions that must be investigated.

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Soils and the Environment. By Alan Wild. 1993. Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211. $69.95, hardcover; $24.95, paper. 287 pp.

The scientific study of soils has been and will continue to be closely linked to agriculture. However, in recent years, the discipline of soil science has expanded considerably beyond its agricultural roots to encompass various environmental issues. *Soils and the Environment*, reflecting this expansion, examines the role of soils both in food production and in maintaining environmental quality. The book is an introductory text covering a wide range of topics, and is particularly suitable for students in environmental science or related fields who need to know the basics of soil science. Because it deals with many aspects of soil science, it does not cover individual topics in great detail. But for those who wish to pursue topics in more depth, the author provides a section with suggestions for future readings, broken down by chapter.

The book is divided into two main parts. Part A (106 pages) is an introduction to soil properties and processes. A basic understanding of chemistry and physics is assumed here. Individual chapters are well organized, with each chapter including an outline of topics, an introduction, and a summary. The author has devoted chapters to soil components, soil development, sorptive properties of soils, soil organisms and processes, and the movement of water, air, solutes, and heat through soil. The text is easy to read, and photographs, figures, and tables are used to illustrate many concepts. The outline style that Wild has used to structure the book provides easy access to specific topics. His goal in this section is to introduce the language and basic principles and processes of soil science to help the reader understand the behavior of soils in supporting crop growth and maintaining a clean environment, and as a source or sink for atmospheric gases. The level of detail is appropriate for students who need a general introduction to soils and their role in the environment. Although Wild provides an excellent summary of basic soil science here, the level of detail could be insufficient for someone looking for a rigorous treatment of the subject.

Part B (181 pages) emphasizes several topical applications of soil science, with individual chapters devoted to the role of soils in plant growth, crop production, soil acidification, and atmospheric gas fluxes. Additional chapters discuss heavy metals and radionuclides in the soil and offer an introduction to soil erosion and conservation. In each chapter, the author provides a brief summary of the topic (often an environmental concern), and then explains the soil's role in it, using examples from the current literature. In the final chapter, Wild portrays the soil as a component in the terrestrial biosphere and discusses soil degradation, drought, and the problems associated with the use of fertilizers and pesticides in intensive agriculture.

The author achieves his stated goal of informing the interested layman and the student about soils' role in plant growth, environmental quality, and atmospheric fluxes. With the caveat that individual topics are not covered in great depth, I would recommend this book as an introductory text for students who may have the opportunity to take just one soils course during their program, because it not only covers basic soil concepts, but also illustrates the application of soil science to a variety of human activities.

Jay Bell, Assistant Professor, Department of Soil Science, University of Minnesota, St. Paul, MN 55108.

Position Available at California State Polytechnic University

California State Polytechnic University, Pomona, seeks applications and nominations for the position of Director of the Center for Regenerative Studies, an interdisciplinary university-based setting for education, demonstration, and research in regenerative practices and technologies. Candidates must have an established record of scholarship and teaching excellence in sustainable or regenerative technologies or related endeavors; they should also possess administrative experience, preferably in an academic setting, including the management of budgets, personnel and academic programs. Successful fund-raising and proposal-writing is important. The candidate should possess a Ph.D. or an appropriate terminal degree.

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Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

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The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

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A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

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